AN EVALUATION OF METHODS FOR UPDATING ORIGIN AND DESTINATION STUDIES

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by

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Joint Highway Research Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

AN EVALUATION OF METHODS FOR UPDATING
ORIGIN AND DESTINATION STUDIES

To: G. A. Leonards, Director
Joint Highway Research Project

June 16, 1966

File: 3-3-33
Project: C-36-54GG

From: H. L. Michael, Associate Director
Joint Highway Research Project

Attached is a Final Report "An Evaluation of Methods for Updating Origin and Destination Studies" by Mr. Marvin Golenberg, Graduate Assistant on our staff. The research project here completed was approved by the Board on June 19, 1964, and has been performed under the direction of Professor W. L. Grecco. Mr. Golenberg also used the report as his thesis for the MSCE degree.

This investigation of commonly used methods of updating origin and destination studies was conducted on Greater Lafayette. Results of the study indicated that growth factor trip distribution methods can be developed to account for new areas of urban growth and that regression analysis for trip prediction combined with the Fratar and Gravity Models yielded the best results. The research will be useful in transportation planning in the metropolitan areas of Indiana.

The report is presented to the Board for the record and for acceptance as fulfillment of the project.

Respectfully submitted,

Harold L. Michael /jgs
Harold L. Michael, Secretary

HLM:jgs

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Final Report

AN EVALUATION OF METHODS FOR UPDATING ORIGIN AND DESTINATION STUDIES

by

Marvin Golenberg
Graduate Assistant

Joint Highway Research Project

File No: 3-3-33

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Purdue University
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ABSTRACT

Golenberg, Marvin. MSCE, Purdue University, June 1966. An Evaluation of Methods for Updating Origin and Destination Studies.
Major Professor: William L. Grecco.

This study was concerned with the evaluation of commonly used methods for updating previous origin and destination studies. Investigated were methods of trip end prediction and interzonal trip distribution models. The trip end prediction techniques were regression analysis, and two types of direct growth factors, interaction and average factor. The trip distribution techniques were the Fratar growth factor model, the Detroit growth factor and the Gravity Model.

This evaluation was performed in Lafayette--West Lafayette, Indiana and was based on a 1952 origin and destination study conducted by the Indiana State Highway Commission.

Because new zones were created in the update, the growth factor distribution models were inadequate. To overcome this difficiency a modified Fratar and a modified Detroit distribution technique were developed. This proved satisfactory and enabled distribution using all study zones.

A method of synthesizing trip purposes was developed based on statistical techniques. This allowed the use of the Gravity Model for distribution of trips by purpose.

Future trip ends were predicted by the three methods and distributed using the Fratar and Detroit Models. Trip ends predicted by regression analysis were distributed by the Gravity Model. In total, seven distributions were performed. The results of these distributions were compared against a screen line field count for evaluation purposes.

Results of this study show that growth factor trip distribution methods can be developed to account for new zones. The distribution of trips by purpose in urban areas is the same regardless of city size. The evaluation against the screen line indicated that regression analysis for trip prediction combined with the Fratar model and with the Gravity Model yielded the best results.

INTRODUCTION

The twentieth century has brought a new dimension in the United States as well as to the other countries in the western world. Technological advances at this time created forces which were to permanently transform living in the western world from rural to urban while at the same time alter the dependance of previous urban living on high density and close proximity. The patterns of population distribution throughout the country began taking the form of nucleations but the distribution of people within these nucleations assumed the form of spatial separation.

Nucleation of people into cities has been attributed to efficient and rapid transportation, the reduction in the cost of transport, the growing ability to produce more from the land, and the increasing demand for goods and services, all byproducts of technological growth. Spatial separation of people, their work, and their places of shopping, education, and amusement came about from the development of intracity transport; first by mass transit and then by automobile.

While mass transit remained as the predominant mode of intracity transport, the trips by the city dwellers were few and highly predictable. Congestion of the streets

in a manner as we know it today was virtually non-existant. This condition gradually changed as the availability and use of the automobile increased without a significant change in the existing system of urban streets. As automobile usage continued to grow, congestion grew with it; urban streets were in a state of distress. The problems of traffic movement were of such magnitude that a systematic and scientific approach toward a solution was warranted (15)*.

The earliest work on traffic flows had been done in rural areas. It was here that the principle of counting traffic was first used along with a very short driver interview to determine the amount of traffic bypassing the urban area. From these studies, it was natural that the first approach to the urban traffic problem would be that of determining the volume of traffic on the street networks. However, the traffic engineer found that even this information was not enough so he divided the city into broad sectors such as the central business district, industrial land. This gave him an insight into the volume of traffic entering and leaving the different areas of the city during all times of the day. This still was not enough. Information had to be known about travel not just to isolated areas, but throughout the entire city. To provide this information the urban origin and destination (O-D) study was developed.

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* Numbers in parentheses refer to Bibliography.

The area of study was divided into analysis zones or tracts with the determination of these zones based on similar land uses. Drivers were interviewed as to the number and origin and destination of the trips they had made during a typical day. The method of interview such as road side interview, post card, home interview, or license plate, was a function of the size of the city (28). Differential flows between zones could be ascertained and the dominance of certain zones as generators and attractors could readily be seen.

The level of urban traffic studies remained at this point until the mid 1940's when further subdivision and analyses of traffic movement took place. Trips were being stratified according to purpose and mode of travel for the study area as a whole and for individual origin destination zones. Some interesting information on the distribution of trips was found as indicated in the following tables 1 and 2 (26).

In 1953, the Detroit Metropolitan Area Traffic Study was begun. Its initiation marked the beginning of a new era in the study of the movement of persons and goods within the urban area. The concept of the comprehensive transportation study which related land use, social and economic values with intracity movement had been initiated. The generation of trips was correlated to these variables and more sophisticated methods of forecasting were develop-

TABLE 1 —Number and percentage of trips by each mode of travel in six population groups, classified according to trip purpose

Mode of travel	Population group	Number of cities	Trip purpose											
			Work and business		Social and recreation		Shop		Miscellaneous		Home		Total	
			Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Automobile drivers	1,000,000 and over	4	1,143,303	35.4	300,892	9.3	201,334	6.2	414,396	12.9	1,165,651	36.2	3,225,576	100.0
Automobile and taxi passengers			344,013	19.1	420,539	23.3	116,687	6.5	151,320	8.4	769,472	42.7	1,802,031	100.0
Mass-transit passengers			1,401,980	28.2	345,528	7.0	309,684	6.2	884,034	17.8	2,027,099	40.8	4,968,325	100.0
Total			2,889,296	28.9	1,066,959	10.7	627,705	6.3	1,449,750	14.5	3,962,222	39.6	9,995,932	100.0
Automobile drivers	500,000–1,000,000	6	1,110,178	31.5	309,475	8.8	296,569	8.4	438,527	12.4	1,370,171	38.9	3,524,920	100.0
Automobile and taxi passengers			289,710	16.6	402,040	23.0	145,159	8.3	156,448	9.0	753,517	43.1	1,746,874	100.0
Mass-transit passengers			983,146	33.0	184,998	6.2	201,002	6.8	190,078	6.4	1,418,248	47.6	2,977,472	100.0
Total			2,383,034	28.9	896,513	10.9	642,730	7.8	785,053	9.5	3,541,936	42.9	8,249,266	100.0
Automobile drivers	250,000–500,000	3	234,358	33.9	72,134	10.4	58,241	8.4	84,678	12.2	242,866	35.1	692,277	100.0
Automobile and taxi passengers			70,884	16.9	110,151	26.3	34,775	8.3	31,456	7.5	172,196	41.0	419,462	100.0
Mass-transit passengers			175,776	30.2	52,309	9.0	42,057	7.2	60,348	10.4	251,271	43.2	581,761	100.0
Total			481,018	28.4	234,594	13.8	135,073	8.0	176,482	10.4	666,333	39.4	1,693,500	100.0
Automobile drivers	100,000–250,000	20	888,964	30.4	287,031	9.8	270,770	9.3	433,692	14.8	1,042,586	35.7	2,923,043	100.0
Automobile and taxi passengers			264,644	16.0	428,819	25.9	146,796	8.9	116,747	7.1	696,795	42.1	1,653,801	100.0
Mass-transit passengers			330,220	26.3	115,567	9.2	104,161	8.3	108,051	8.6	596,264	47.6	1,254,263	100.0
Total			1,483,828	25.4	831,417	14.3	521,727	8.9	658,490	11.3	2,335,645	40.1	5,831,107	100.0
Automobile drivers	50,000–100,000	12	242,565	30.0	87,961	10.9	65,073	8.0	117,711	14.6	294,964	36.5	808,274	100.0
Automobile and taxi passengers			79,696	17.5	120,083	26.3	35,941	7.9	24,855	5.5	195,281	42.8	455,856	100.0
Mass-transit passengers			110,197	29.8	33,696	9.1	28,778	7.8	24,280	6.6	172,236	46.7	369,187	100.0
Total			432,458	26.5	241,740	14.8	129,792	7.9	166,846	10.2	662,481	40.6	1,633,317	100.0
Automobile drivers	Less than 50,000	5	60,480	29.0	22,449	10.8	18,844	9.0	35,369	16.9	71,680	34.3	208,822	100.0
Automobile and taxi passengers			16,414	13.9	38,750	32.9	9,440	8.0	5,720	4.9	47,368	40.3	117,692	100.0
Mass-transit passengers			12,784	26.6	4,389	9.2	4,753	9.9	3,670	7.6	22,423	46.7	48,019	100.0
Total			89,678	24.0	65,588	17.5	33,037	8.8	44,759	11.9	141,471	37.8	374,533	100.0
Automobile drivers	All groups	50	3,679,848	32.3	1,079,942	9.5	910,831	8.0	1,524,373	13.4	4,187,918	36.8	11,382,912	100.0
Automobile and taxi passengers			1,065,361	17.2	1,520,382	24.5	488,798	7.9	486,546	7.9	2,634,629	42.5	6,195,716	100.0
Mass-transit passengers			3,014,103	29.5	736,487	7.2	690,435	6.8	1,270,461	12.5	4,487,541	44.0	10,199,027	100.0
Total			7,759,312	27.9	3,336,811	12.0	2,090,064	7.5	3,281,380	11.8	11,310,088	40.8	27,777,655	100.0

TABLE 2.—**Percentage of trips for each trip purpose in six population groups, classified according to mode of travel**

Purpose of trip	Population group	Number of cities	Mode of travel			
			Automobile drivers	Automobile and taxi passengers	Mass-transit passengers	Total
Work and business	1,000,000 and over	4	39.6	11.9	48.5	100.0
Social and recreation			28.2	39.4	32.4	100.0
Shop			32.1	18.6	49.3	100.0
Miscellaneous			28.6	10.4	61.0	100.0
Home			29.4	19.4	51.2	100.0
All purposes			32.3	18.0	49.7	100.0
Work and business	500,000–1,000,000	6	46.6	12.2	41.2	100.0
Social and recreation			34.5	44.9	20.6	100.0
Shop			46.1	22.6	31.3	100.0
Miscellaneous			55.9	19.9	24.2	100.0
Home			38.7	21.3	40.0	100.0
All purposes			42.7	21.2	36.1	100.0
Work and business	250,000–500,000	3	48.7	14.7	36.6	100.0
Social and recreation			30.7	47.0	22.3	100.0
Shop			43.1	25.7	31.2	100.0
Miscellaneous			48.0	17.8	34.2	100.0
Home			36.5	25.8	37.7	100.0
All purposes			40.9	24.8	34.3	100.0
Work and business	100,000–250,000	20	59.9	17.8	22.3	100.0
Social and recreation			34.5	51.6	13.9	100.0
Shop			51.9	28.1	20.0	100.0
Miscellaneous			65.9	17.7	16.4	100.0
Home			44.7	29.8	25.5	100.0
All purposes			50.1	28.4	21.5	100.0
Work and business	50,000–100,000	12	56.1	18.4	25.5	100.0
Social and recreation			36.4	49.7	13.9	100.0
Shop			50.1	27.7	22.2	100.0
Miscellaneous			70.6	14.9	14.5	100.0
Home			44.5	29.5	26.0	100.0
All purposes			49.5	27.9	22.6	100.0
Work and business	Less than 50,000	5	67.4	18.3	14.3	100.0
Social and recreation			34.2	59.1	6.7	100.0
Shop			57.0	28.6	14.4	100.0
Miscellaneous			79.0	12.8	8.2	100.0
Home			50.7	33.5	15.8	100.0
All purposes			55.8	31.4	12.8	100.0
Work and business	All groups	50	47.4	13.7	38.9	100.0
Social and recreation			32.4	45.5	22.1	100.0
Shop			43.6	23.4	33.0	100.0
Miscellaneous			46.5	14.8	38.7	100.0
Home			37.0	23.3	39.7	100.0
All purposes			41.0	22.2	36.8	100.0

ed. The study of urban area movement had evolved from the use of a program of counting to the more sophisticated trip production factors.

The evolution of forecasting future trip distribution follows closely that of the development of urban movement studies. The first attempt at trip prediction was to obtain an overall view of the area and from this, determine a uniform growth factor for updating trip interchanges. Later methods utilized different growth indicators for each zone within the area along with more sophisticated methods of trip distribution. With the arrival of the comprehensive approach and large electronic computers, synthetic methods for determining trip generation and distribution were developed, and these were based on a previous O-D study.

PURPOSE AND SCOPE

Many techniques have been developed in the evolution of the urban area transportation study. The first techniques, although crude in comparison to present methods, provide the framework for the development of present and future techniques. With refinements and new developments, the earlier attempts were discarded. Presently there are several methods being used for the prediction and distribution of urban area trips. It shall be the purpose of this study to evaluate the most commonly used techniques in an attempt to find a procedure that will adequately predict future travel patterns and at the same time minimize the time, money, and information required.

The study consists of two parts: an evaluation of future trip generation methods; an evaluation of trip distribution models. In the first part the two methods of trip generation analyzed are statistical regression analysis and direct factor techniques. For the distribution evaluation, the Detroit Model, the Fratar Model, and the Gravity Model will be investigated.

Different trip generation methods and distribution techniques will be combined and the results will be compared to traffic counts made at selected locations. In addi-

tion to this, the various combinations will be compared to determine if there is any significant statistical difference between them.

REVIEW OF LITERATURE

Prediction of future trips

Growth in trips generated by study zones has in the past been computed by several different techniques. Using the previous O-D as a base, future trip ends are computed by the same techniques for both updating and prediction. In actuality, the only difference between updating and prediction is the accuracy of the variables used. When updating is done, exact values of the prediction variables are determined, while in prediction, the values of the variables for the future years are estimated. The review of existing techniques will cover both cases of trip generation.

Methods of determining travel growth can be grouped in three main categories, regression analysis, land use generation rates, and direct factor methods. (3,8,13,25)

Regression

Sharpe, Hansen and Hamner in their study of trips on residential land found that automobile registration was the best predictor of trips from residential land (3). They examined the following variables; vehicle ownership, population density, population, income, and distance from the central business district and developed prediction equations for the two years, 1948 and 1955. The two equations are:

1948 $Y = 0.9 + 0.04x$

1955 $Y = 0.6 + 0.04x$

Where Y = residential trips per person

x = passenger cars per 100 people

The intercept difference is explained by an increase in automobile ownership rate.

Using the data from the Modesto, California O-D Study, Shuldiner also developed prediction equations for trip generation from the home (27). He used two different approaches in preparation of his data, first by grouping the data O-D zones, and then by classifying the data on the basis of dwelling units. Although several variables were considered, the prediction models were developed using vehicles per dwelling unit and persons per dwelling unit. Two sets of three equations were developed, one for each approach in data preparation. For individual dwelling units, the three equations were:

1a) $T = 0.467 + 0.831p$

$R^2 = 0.22$

$r_e = 0.76$

$c\% = 25.4$

2a) $T = 1.229 + 1.379v$

$R^2 = 0.19$

$r_e = 0.78$

$c\% = 26.0$

3a) $T = -0.137 + 0.632p + 0.950v$

$R^2 = 0.30$
$r_e = 0.72$
$c\% = 24.0$

For the origin and destination zones the three equations were:

1b) $T = -0.627 + 1.216p$

$R^2 = 0.67$
$r_e = 0.51$
$c\% = 17.0$

2b) $T = 0.653 = 1.850v$

$R^2 = 0.49$
$r_e = 0.62$
$c\% = 20.7$

3b) $T = 0.648 + 0.964p + 0.608v$

$R^2 = .69$
$r_e = 0.49$
$c\% = 16.3$

T = average daily number of person trips from home
p = number of persons per dwelling units
v = number of vehicles per dwelling unit

R^2 = coefficient of determination
r_e = standard error
$c\%$ = coefficient of variation

It appears that the second set of equations, using the study zones for variable grouping, is better for predicting trips then the individual dwelling units, as indicated by the higher R squares. The best equations for trip prediction appears to be 1b and 3b.

In another study conducted in California, Spiegleman and Duke developed regression models for the prediction of work trips in the study area (30). Their work was done in San Mateo County, California and utilized a minimum amount of input data. Only work trips were studied because they felt that work trips during the peak hour movement (when most work trips occur) would be a good measure of the traffic volumes on the street system.

The model developed for the prediction of work trips in each zone was:

(1) $W_i = 74.6 + 0.86E_i - 31.8H/p_i$

(1a) $W_i = -63.4 + 0.575E_i + 0.108p_i$

Where equation 1a was used in combination with equation 1 in a few small densely populated areas. Supplementary equations developed were:

(2) $E_i = -136.6 + 0.449Z_i P_i + 0.99H_i$

(3) $P_i = H_i p_i$

(4) $P_i = 6.67 - 5.36Z_i - 1.14B_i/H_i$

(5) $Z_i = 0.255 + 0.5044Z_i + 0.086B_i/H_i - 0.0011H_i/A_i$

(6) $H_i = \overline{H}_i$

(7) $A_i = \overline{A}_i$

(8) $B_i = \overline{B}_i$

(9) $B_i = 47{,}950 + 0.50\,(H_i - H_i^o)$

(10) $P_i = \dfrac{E_i + 13{,}250 - 0.499H_i}{0.449Z_i}$

(11) $Z_i = \overline{Z}_i$

Where W_i = work automobile trips in zone i

E_i = employed residents in zone i

H_i = households in zone i in design year

A_i = gross residential acres in zone i

P_i = population in households in zone i

Z_i = proportion of population between 18 and 64 in design year in zone i

Z_i^o = proportion of population between 18 and 64 in present year in zone i

p_i = average population per household in zone i

B_i = number of rental household units in zone i

H_i^o = household in present year in zone i

Since these equations were used in conjunction with the gravity model for distribution of trips, a supplementary set of equations was also developed to predict the relative attractiveness of each work zone.

Other studies have been conducted which investigated the prediction of single purpose or single production zone trips. Trips, generated by the CBD or more correctly attracted by the CBD, have received considerable study in several large cities in North America. Harper and Edwards investigated the ability to predict person trips in areas within the CBD (13). Their study used information collected in seven large cities over a period of several years. Results indicated the variables that could be used to predict trips were retail floor space, service-office floor space, and manufacturing-warehouse floor space. In the seven cities, the percent that could be explained by these variables ranged from 66.7% to 99.7%.

The equations that were developed are:

Philadelphia

$$Y = -3{,}470 + 14.60x_1 + 5.858x_2 + 1.276x_3 \quad R^2 = 0.96$$

Detroit

$$Y = -2{,}280 + 13.918x_1 + 4.613x_2 + 1.717x_3 \quad R^2=0.997$$

Baltimore

$$Y = -1{,}080 + 12.871x_1 + 4.524x_2 + 1.343x_3 \quad R^2=0.667$$

Seattle

$$Y = -200 + 13.678x_1 + 4.382x_2 + 0.152x_3 \qquad R^2 = 0.965$$

Vancouver

$$Y = 1,560 + 14.322x_1 + 10.534x_2 + 3.670x_3 \qquad R^2 = 0.963$$

Tacoma

$$Y = 3,590 + 7.709x_1 - 2.493x_2 -17.692x_3 \qquad R^2 = 0.997$$

Dallas

$$Y = 8,570 + 16.191x_1 + 3.546x_2 + 12.265x_3 \qquad R^2 = 0.920$$

Where

Y = number of person destinations in a zone in the CBD in an average 24 hour period within the metropolitan area.

x_1 = area of retail floor space in use in the zone expressed in thousands of square feet.

x_2 = area of service-office space in use in the zone expressed in thousands of square feet.

x_3 = area of manufacturing-warehousing floor space expressed in thousands of square feet.

Prediction equations of this type could be used to predict total trip ends in commercial O-D zones.

A comparative study of trips to the CBD in Lexington, Kentucky was done by Dearinger for the years, 1952 and 1957 (7). Dearinger found that total automobile trips to the CBD could be predicted from vehicle registrations; shopping

trips to the CBD could be predicted by vehicle registration and residential densities, and business work trips by zonal population. From his work, there appears to be a change in the prediction equations with time. The equations developed are:

1952

(1) $\log Y_t = \log 1.764 - 0.767 \log X_v$ $\quad r = 0.890$, $S_{yx} = \pm 0.13062$

(2) $Y_s = 7.85 + 0.001X_v$ $\quad r = .0848$, $S_{yx} = \pm 1$[illegible]

(3) $Y_{bw} + 72.6 + 0.19X_v$ $\quad r = .356$, $S_{yx} = \pm 55$

1957

(4) $\log Y_t = \log 0.608 + 0.91 \log X_v$

(5) $Y_s = 11.94 + 0.053X_v$

(6) $Y_{bw} = 48.7 + 0.141X_v$

where: X_v = the total number of passenger cars registered in a study zone/acre

X_p = the total zonal population/acre

Y_t = total trips to CBD/100 acres

Y_s = total number of shopping trips to the CBD/100 acres

Y_{bw} = the total number of business-work trips to the CBD/100 acres

Dearinger also tried to predict total trips to the CBD using density as the only variable. The resulting equations was:

$$Y_t = 14.5 + 25X_d \qquad r = 0.825 \quad S_{yx} = \pm 56$$

where: Y_t = total trips to the CBD per 100 acres

X_d = average number of dwellings per acre

Other prediction equations were developed using distance from the CBD, vehicle density and persons per acre, but their coefficient of determination was less than 60%.

The Hamilton Area Transportation Study developed several prediction equations for the distribution of trips by purpose (16). These models were developed from selected zones within the study area and were used to determine the trips in the remaining study zones. Detailed analysis as to purpose was necessary because the gravity model was used for distribution of the predicted trip ends. The following six models were developed to predict trips produced in each zone per family:

1.) $Y_w = +0.0429+0.219\ X_1 \qquad r = 0.829 \quad S = \pm 0.084$

2.) $Y_s = -0.598+1.323\ X_2 \qquad r = 0.890 \quad S = \pm 0.163$

3.) $Y_{sr} = -0.117+0.896\ X_2 \qquad r = 0.693 \quad S = \pm 0.163$

4.) $Y_{nw} = -0.882 + 2.718\ X_2$ $\qquad r = 0.931$, $S = \pm\ 0.187$

5.) $Y_{nh} = -1.042 + 2.218\ X_2$ $\qquad r = 0.815$, $S = \pm\ 0.276$

6.) $Y_t = -1.51 + 8.91\ X_2$ $\qquad r = 0.958$, $S = \pm\ 0.467$

where: Y_w = work trips per family

Y_s = shopping trip per family

Y_{sr} = social recreational trips per family

Y_{nw} = non-work home origin trips per family

Y_{nh} = non home based trip per family

Y_t = total trip per family

X_1 = person per family

X_2 = automobiles per family

With the exceptions of work trips, all trips could be predicted using the number of automobiles per family.

The gravity model was used for trip distribution. Attraction factors were developed for work trips using total zonal employment and for shopping trips using zoning retail employment. Distribution of social recreational, home based other, and non home based trips, was performed using a factor based on the weighted combination of zone population and employment.

The Chicago Area Transportation Study and the Pittsburgh Area Transportation Study had a different approach to trip prediction by regression techniques (6,23).

In Chicago they estimated the total number of person trips in the study area for the design year and then by a separate analysis distributed these trip ends to the different land uses. Total person trips were estimated without any relation to origin-destination and trip purpose. It was hypothesized that population density and automobile ownership would be the most important prediction variables. Population density shows the need for movement and automobile ownership shows the opportunity for movement. The fitted equation for this relationship was:

$$Y_c = 682.84 + 3.8109X_2 - 0.1939 \log X_3$$

where: Y_c = computed trips per dwelling unit

X_2 = cars per hundred dwelling units

X_3 = dwelling units per 10 acres.

Trips for the design year were computed using aggregate of the predicted data for each zone while the total trips were obtained by summing the trips produced in each zone. Distribution was then made to the five major land uses.

The Pittsburgh Study used a similar approach by correlating trips per family or dwelling place with residential density and automobile ownership. From the existing 1958 trip data the following prediction equations were developed:

1.) $Y_1 = 9.62 - 4.19 \log X$ $r = -0.88$

2.) $Y_2 = 5.55 - 2.64 \log X$ $r = -0.91$

3.) $Y_1 = -0.29 + 6.51X_1$ $r = +0.91$

4.) $Y_2 = -0.76 + 4.19X_1$ $r = +0.96$

5.) $Y_{10} = 0.09 + 3.13X_1$ $r = +0.85$

6.) $Y_{11} = 0.02 + 1.91X_1$ $r = +0.85$

7.) $Y_{10} = 5.02 - 2.17 \log X$ $r = -0.87$

8.) $Y_{11} = 3.05 - 1.35 \log X$ $r = -0.90$

Where Y_1 = person trips per family

Y_2 = auto trips per family

Y_{10} = person destinations per dwelling place

Y_{11} = auto destinations per dwelling place

X = dwelling places per residential acre

X_1 = automobiles per dwelling unit

To predict trips for the design year, future automobile ownership and residential densities were predicted for the study rings. These estimates were used with the prediction equations to produce an estimate of the total trips in the study area. Distribution of trip ends to individual zones was performed by utilizing land use analysis.

Regression analysis enables the establishment of a relationship between trips and the factors which generate these trips. Coupled with the prediction of these variables for the future year, trips can be estimated. It must be realized that these equations are only valid with the ranges of the regression analysis.

Land Use Generation Rates

A technique for predicting future trip ends in an O-D zone, that has received considerable attention in the past few years, is the generation of trip ends by certain types of land use. Several metropolitan transportation agencies and consulting engineers have generally accepted the land use generation approach for estimating design year trips.

The Detroit Metropolitan Traffic Study was the first modern era urban transportation study to use land use generation techniques (8).

Prediction of future zonal trip ends was based on the amount of future acres of each land use type in the respective study zones. Trip production rates were determined

for each land use for different areas of the city based on density, income, and distance from the CBD. From these, total trip ends in the individual zones were calculated using production rates for the particular area and total acres of each land use within the zone.

McGrath's work in the New Haven Metropolitan Area used the generation characteristics of each land use type as inputs for the determination of future travel patterns (12). The procedure used by McGrath was to thoroughly analyze the different areas of the city by investigating vehicle ownership, land use distribution, and intensity of development. Future measures of these variables were then predicted using standard trending and land use projection techniques. Determination of trips was then performed by using production and attraction rates for trip ends based on the respective variables. The values used in New Haven were:

Trip Production

1. Three trip ends per passenger car in zone of registration.
2. Four trip ends per truck in proportion to effective industrial and commercial average of the zone based on the total effective industrial and commercial average of the survey area.

for each language [illegible]

density, [illegible] and distribution [illegible]

[illegible]

Trip Attraction

1. One hundred trip ends per effective industrial acre.
2. Two hundred trip ends per effective commercial acre.
3. One-half trip end per passenger car in zone of registration.

The term "effective acre" was applied to a standard or average developed land use. This standard was taken as 100%. Land use in other zones was compared to this and a ratio of high or low intensity of development as determined using the standard as a base. From this, the ratio was applied to production and attraction and adjustments made to these trip rates.

Voorhees took a similar approach in synthesizing future trip ends in the study area (31). Voorhees divided the area trips into four types: home to work trips, home to commercial trips; home based social trips; and non home based trips. His procedure was then to apply suitable factors relating land use generation to these trip classifications to obtain generated trip ends in a zone. Generation rates were based on vehicle ownership in a zone for commercial and social trips. For every 1,000 automobiles registered in a zone, 800 commercial trip ends and 400 social trip ends were generated. Work trip end generation was based on 85 trips per 100 people in the labor force

living in the zone. Non home based trip end generation was determined by either using a rate of 1,200 trips per 1,000 vehicles or by taking the number of trips as equal to the number of people employed in the zone plus five times the retail employment, depending upon the zone's land use. A necessary input for prediction of trip ends is the predicted number of future automobile registrations and employment within the study zones. Before future trips could be distributed, an adequate measure of attraction had to be determined.

Wilbur Smith and Associates, in studies conducted in various cities, have used trip production rates per unit of land use measurement and predictions of future land use variables in order to estimate future zonal trip ends (29). Trips were stratified according to purpose, worker types, distance from the CBD, and income. For work trips, the number of workers in a zone was used as the best determinant. Typical values developed in Nashville, Tennessee were 1.53 trips per white collar worker and 1.73 trips per worker. In general, the average was between one and one-half and two one-way trips per worker. Convenience shopping trip generation rates were found to be a function of distance from the CBD; with values in Nashville ranging from 18 trips per acre in the CBD to 67 trips per acre at a distance of 4 miles from the CBD. Trip rates for general apparel and furnishing purchases decreased with distance

from the CBD, with 48 trips per commercial acre in the core and decreasing to 6.3 trips for the remaining area. Business trips varied from 49 trips to 21 trips for commercial acre for the same area. Trip rates for the school trips were best determined from income levels, with high incomes producing more trips per person than lower income groups. The range was 0.32 trips per student to 1.25 trips per student. Income was also the determinant for social trip production, with 0.58 trip per dwelling unit produced in the lowest income group ranging to 1.59 trips per dwelling unit for the highest income group. Trip generation in residential zones was found to vary with income ranging from 1.4 trips per person for low income groups to 3.0 trips per person for high income groups.

In work done by Pollard and Guyton, trip generations per unit of land use type was used to predict future zonal trip generations (24). This was accomplished by determining future units of land use in each study zone and applying the appropriate generation rate to determine total trip ends. However, Pollard and Guyton felt that increased trip potential must be accounted for and that the future trip ends must be modified by an automobile registration adjustment factor.

Land use effects on trip generation was employed in a different manner by both the Chicago Area Transportation Study and the Pittsburgh Area Transportation Study (6,23). Total area future trips were predicted by regress-

from the [illegible]
and deco[illegible]
mass [illegible]
accre[illegible]
with [illegible]
periods [illegible]

In a different [illegible]
tion study [illegible]
(6,23). Total area [illegible] were [illegible] regres-

ion techniques with no attempt to assign these trips to the study zones. To determine where these trips would originate and terminate, land use characteristics were employed. Future land use was estimated for the entire study area and a relationship between distribution of trip to land use type and number of trips per household was established. This produced a distribution of the future total trips to the various land uses on a total area basis. Using future land use information, trips were distributed to each zone, based on trip generation per unit of the particular land use type as a function of the distance from the CBD and certain characteristics of the land use type. In this manner, future trip ends for the study area were determined for each origin and destination zone.

Land use has been used for both synthesis of trip production in specific zones and for distribution of trip ends determined by other means. Variations are evident in the generation potential of land use, both by trip purpose and by city. Because of this, care should be exercised in the selection or determination of the generation rates used in any particular city. Many transportation studies have been performed using land use generation techniques and these techniques have contributed much toward improved and lower cost studies.

Direct factor methods

Perhaps the oldest technique for predicting future

trip ends in the urban area are the direct factor methods. In early studies, future trips were estimated by adjusting the base zonal interchange by an intuitive factor. As a result of dissatisfaction with the single factor approach, methods of determining individual zonal growth factors were developed.

In 1953, the Minnesota State Highway Department in cooperation with the Bureau of Public Boards developed methods of predicting future trips for the Minneapolis-St. Paul C-D area (3). Their procedure was to predict trips by direct factor methods with the end result being a land use factor for each zone.

The following is a summary of this method:

a) Determine dwelling unit factor (D.U.F.)

$$\text{D.U.F.} = \frac{\text{estimated design year dwelling units}}{\text{present dwelling units}}$$

b) Determine commercial factor (C.F.)

$$\text{C.F.} = \frac{\text{estimated design year commercial developments}}{\text{present commercial developments}}$$

c) Residential trips in a zone = (D.U.F.)(Present residendial trips)

d) Commercial trips in a zone = (C.F.)(Present commercial trips)

e) Land Use Factor (L.U.F.)

$$\text{L.U.F.)} = \frac{\text{design year trips}}{\text{present year}}$$

Factors were computed for each zone and a distribution of trips was made by a factor distribution model.

Factor techniques were employed in the Houston Traffic Study to update base 1953 travel patterns to 1960. Trips in the 1953 study zones were updated by factor methods while trips in new or added zones were determined from an interview survey. The 1953 trips in the original zones were divided into three portions, auto driver trips, auto-passenger trips and commercial vehicle trips. Expansion of auto driver and passenger trips was done by using a zone population factor.

The zone population factor was calculated by dividing the 1960 zone population by the 1953 zone population. Additional factoring was necessary to account for a 1.5% annual increase in auto driver trips and a 0.7% annual increase in auto passenger trips. Treating the annual increase as compound interest, the resulting factor for these two types of trips were:

1) 1960 auto driver trip factor =

$$\frac{(\text{1960 population})}{(\text{1953 population})} \quad (1.015)^7$$

2) 1960 auto passenger trip factor =

$$\frac{(\text{1960 population})}{(\text{1953 population})} \quad (1.007)^7$$

Commercial trips did not show an increase in rate of use. The commercial trip factor was computed using only commercial vehicle registration and was:

$$\text{Commercial trip factor} = \frac{\text{1960 commercial vehicle registration}}{\text{1953 commercial vehicle registration}}$$

Taxi cab trips were assumed to remain the same (34).

Pollard and Guyton have suggested using a number of variables in the determination of growth factors (24). In their approach the interaction between the variables is used to compute the final factors for the overall area factor and factors for the individual zones. For zonal factors, the values of the variables for the specific zones are employed. The computational form is:

$$\text{Factor} = \frac{(\text{population rates})(\text{automobile regis. rates})}{(\text{automobile usage rates})}$$

Direct factor techniques yield reasonable results in zones which have small land use changes and remain relatively stable overtime. Difficulty is encountered in determining factors for rapidly changing zones, with these factors approaching values of 25 or more. Inclusion of new zones in the study creates a problem because no previous information exists, resulting in infinite growth factors. Generally, direct factor methods can only be used in a stable zone, with a modified factor approach for unstable and new zones.

Trip distribution models

Distribution of trips in the urban area has proved an interesting problem for the past 30 years. Attempts have

been made to develop techniques by which trips in the study area could be allocated between zones. The models which have been developed to-date can be classified as either growth factor models or inter-area models. Growth factor models are based on the principle that future trips are analogous to present trips modified by zonal growth factors. Inter-area models are developed from base O-D data and are used to synthesize travel patterns based on certain travel characteristics.

The following is a list of the models that have been developed:

1. Growth Factor Methods
   Uniform Factor
   Average Factor
   Detroit Model
   Fratar Model

2. Inter-Area Travel Formulas
   Gravity Model
   Bureau of Public Roads Model
   Inter-Area Travel formulas
   Electrostatic model
   Interactance Model
   Linear Programming Model
   Opportunity Model
   Competing Opportunities Model
   Multiple Regression Model

Cost Method Model

Systems Engineering Model

In this evaluation study, only the Detroit Model, the Fratar Model, and the Gravity Model will be investigated.

Growth factor models

Growth factor techniques as a method of predicting interzonal trip movement are all based on the principle that the estimated trips follow a pattern similar to that of the base study travel modified by the relative changes in attraction between the terminal zones. The first approach in using growth factor techniques was the uniform factor method. A single growth factor was computed for the area and all trips were modified by this one factor. Differential growth was not accounted for then. To include this effect, the average factor method was developed.

This model takes the form:

$$T'_{ij} = T_{ij} \left(\frac{(F_i + F_j)}{2} \right)$$

$$F_i = \frac{T_i^p}{T_i} \qquad F_j = \frac{T_j^p}{T_j}$$

where T'_{ij} = trips between i and j for the base year

T'_{ij} = trip ends between i and j for the design year

T_i = trip ends in zone i for base year

T_j = trip ends in zone j for base year

T^p_i = trip ends predicted in zone i

T^p_j = trip ends predicted in zone j

F_i = growth factor in zone i

F_j = growth factor in zone j

The model tends to over or under predict trips in the zone so that an iterative process must be used to provide a balanced trip interchange for the area. On iteration, the model becomes

$$T''_{ij} = T'_{ij} \left(\frac{(F'_i + F'_j)}{2} \right)$$

$$F'_i = \frac{T^p_i}{T'_i}, \qquad F'_j = \frac{T^p_j}{T'_j},$$

where F'_i = computation growth factor for zone i

F'_j = computation growth factor for zone j

T'_i = total trip ends in zone i by previous iteration

T'_j = total trip ends in zone j by previous iteration

T''_{ij} = trips from i to j from the present iteration

The iterative process continues until the factors, F'_i $(i = 1, \ldots n)$ approach unity.

A further refinement in growth factor distribution models occurred with this development of the Fratar technique for the Cleveland Transportation Study (11).

Fratar postulated that future trip patterns are based on the previous zonal interchange modified by the interaction of the zonal attraction or growth factors normalized by the effect of the remaining zonal growth factors.

The mathematical derivation of the model is of the following:

$$T_{i \rightarrow j} = \left(t_{ij} \cdot F_i \cdot F_j\right)\left(\frac{\sum_{k=1}^{n} t_{ik}}{\sum_{k=1}^{n} (F_i \cdot t_{ik})}\right)$$

$$T_{j \rightarrow i} = \left(t_{ij} \cdot F_i \cdot F_j\right)\left(\frac{\sum_{j=1}^{n} t_{jk}}{\sum_{k=1}^{n} (F_k \cdot t_{jk})}\right)$$

Let

$$L_i = \frac{\sum_{k=1}^{n} t_{ik}}{\sum_{k=1}^{n} (F_k \cdot t_{ik})}$$

$$L_j = \frac{\sum_{k=1}^{n} t_{jk}}{\sum_{k=1}^{n} (F_k \cdot t_{jk})}$$

The most probable number of trips between i and j:

$$T_{ij} = \frac{T_{i \rightarrow j} + T_{j \rightarrow i}}{2}$$

Making the simplifying substitutions,

$$T_{ij} = \left(\frac{t_{ij} \cdot F_i \cdot F_j \cdot L_i}{2}\right) + \left(\frac{t_{ij} \cdot F_j \cdot F_i \cdot L_j}{2}\right)$$

$$T_{ij} = \left(t_{ij} \cdot F_i \cdot F_j\right)\left(\frac{(L_i + L_j)}{2}\right)$$

This is the final computational form of the model. As in all growth factor models, a series of iterationsare necessary to provide balance in the trip patterns.

Following Fratar's development of a growth factor distribution technique in Cleveland, the next contribution came from the Detroit Metropolitan Area Traffic Study (4). This technique has become known as the Detroit Method of trip distribution. The rational behind this model is that the trips from zone i to zone j in the future year will be attracted to i and j directly proportional to the amount of growth in the two zones. However, to avoid gross over distribution, a measure of resistance to future movement between these two zones was introduced which was equal to the inverse of the entire area growth factor.

Mathematically this can be expressed as

$$T_{ij}' = \left(t_{ij}\right)\left(\frac{GF_i \cdot GF_j}{GF}\right)$$

where: T_{ij}' = future trip between zone i and zone j

t_{ij} = present trips from zone i and zone j

GF_i = growth factor for zone i

GF_j = growth factor for zone j

GF = area growth factor

After distribution from all zone i to all zone j, the trips to each zone are summed and compared to the predicted zone trip ends and a new growth factor is calculated for each zone:

These are expressed as:

$$GF_i' = \frac{T_i}{\sum_{j=1}^{n} T_{ij}'}$$

$$GF_j' = \frac{T_j}{\sum_{i=1}^{n} T_{ij}'}$$

$$GF' = T \Big/ \left(\sum_{i=1}^{n} \sum_{j=1}^{n} T_{ij}' / 2 \right)$$

where: GF_i' = growth factor for zone i after the first distribution

GF_j' = growth factor for zone j after the first distribution

GF' = area growth factor after the first distribution

T_i = predicted trip ends in zone i

T_j = predicted trip ends in zone j

T = predicted total area trip ends

An iterative process of distribution is continued until all growth factors approach unity.

The following is a list of the advantages and disadvantages of the growth factor methods (20).

Advantages

1. Growth factor methods are basically simple,

well tested, and require no distance parameters (travel time, distance, etc.)

2. They can be applied to directional peak hour flows as well as for average daily traffic in the urban area. They can be used for different trip purposes or for trips between specific land uses.
3. Growth factor methods are especially useful in updating recent O-D survey data.

Disadvantages:

1. Growth factor methods require a comprehensive O-D study to provide the necessary input data (t_{ij}'s)
2. Possible major changes in the urban area are not recognized, in that growth factor methods:
   - a.) require rigid zonal and regional boundaries
   - b.) assume that travel resistance will remain constant with time (or that the urban transportation facilities will be improved sufficiently to maintain present travel resistance)
   - c.) cannot be used effectively if there are substantial changes anticipated in land use patterns.

3. Weakness in handling small interchange volumes.
    a.) If the present zonal interchange volume is zero, the predicted future interchange volume must necessarily remain zero.
    b.) Instability of small numbers of events is preserved in future intrazonal estimates.

4. The results are not independent of arbitrary distribution procedures, and are subject to iteration inaccuracies.
5. Growth factor methods depend upon the accurate determination of zonal growth factors, which cannot usually be done in terms of a single numerical value.

Gravity Model

The first written material on the gravity concept of attraction between two or more populated areal zones appeared in 1858. Carey first proposed the concept that an attraction existed between zonal groups for social and physical interaction in a manner analagous to Newton's law of gravitational attraction between two masses. Ravenstein in 1885 proposed that migration of people could be determined by a method based on the gravitational attraction theory and in 1920, Young also proposed the use of the gravity theory in migration studies. In 1929, Reilly in studies on the attraction to shopping areas developed his

theory of law of retail gravitation which again was an adaptation of Newton's basic law. It has generally been acknowledged that Reilly's work was the beginning of the use of the gravity concept in traffic movements. Zipf and Stewart were the next major contributors to the use of the gravity concept for inter-area movements of people (5). In 1946 Zipf proposed his $P_1 P_2 / D$ hypothesis for inter-area trip movement based on population as the attractor and distance as the resistance. By the early 1950's, the gravity concept had been sufficiently advanced with its application in several other areas of human behavior. The next most significant advance in the gravity concept applied to traffic movement occurred in 1955 when Voorhees developed a gravity type model for the distribution of urban area trips.

Voorhees' model was developed to distribute trips between study zones in the urban area. The model closely follows the gravity law and takes the form:

$$T_{i-j} = t_i \cdot \frac{A_j}{D^x_{i-j}}$$

where T_{i-j} = total number of two way trips between zones 1 and j

T_i = total trip ends generated by zone i

A_j = attractive force of zone j

D_{i-j} = automobile travel time between zone i and j

D_{i-k} = travel time between zone i and zone k $k=1,\dots n.$

A_k = attractive force of zone k, $k=1,\dots n.$

x = empirically determined exponent

Since the model tends to over and under distribute trips, a normalization is required to bring about a balance in the distribution. This term is of the form:

$$\sum_{k=1}^{n} \frac{A_k}{(D_{i-k})^x} \quad \text{and the model becomes} \quad \underset{k\neq i}{T_{i-j}} = \frac{\dfrac{T_i \, A_j}{D_{i-j}^{\,x}}}{\displaystyle\sum_{k=1}^{n} \frac{A_k}{D_{i-k}^{\,x}}}$$

Voorhees found that better results could be obtained if the trips emanating from a production zone were stratified according to trip purpose. Separate exponents and indices of attraction could then be used as a measure of the pull between the productions and attractions of each trip purpose to be used. The characteristics of each trip's purpose that are inputs to the model are presented in table 3 (32).

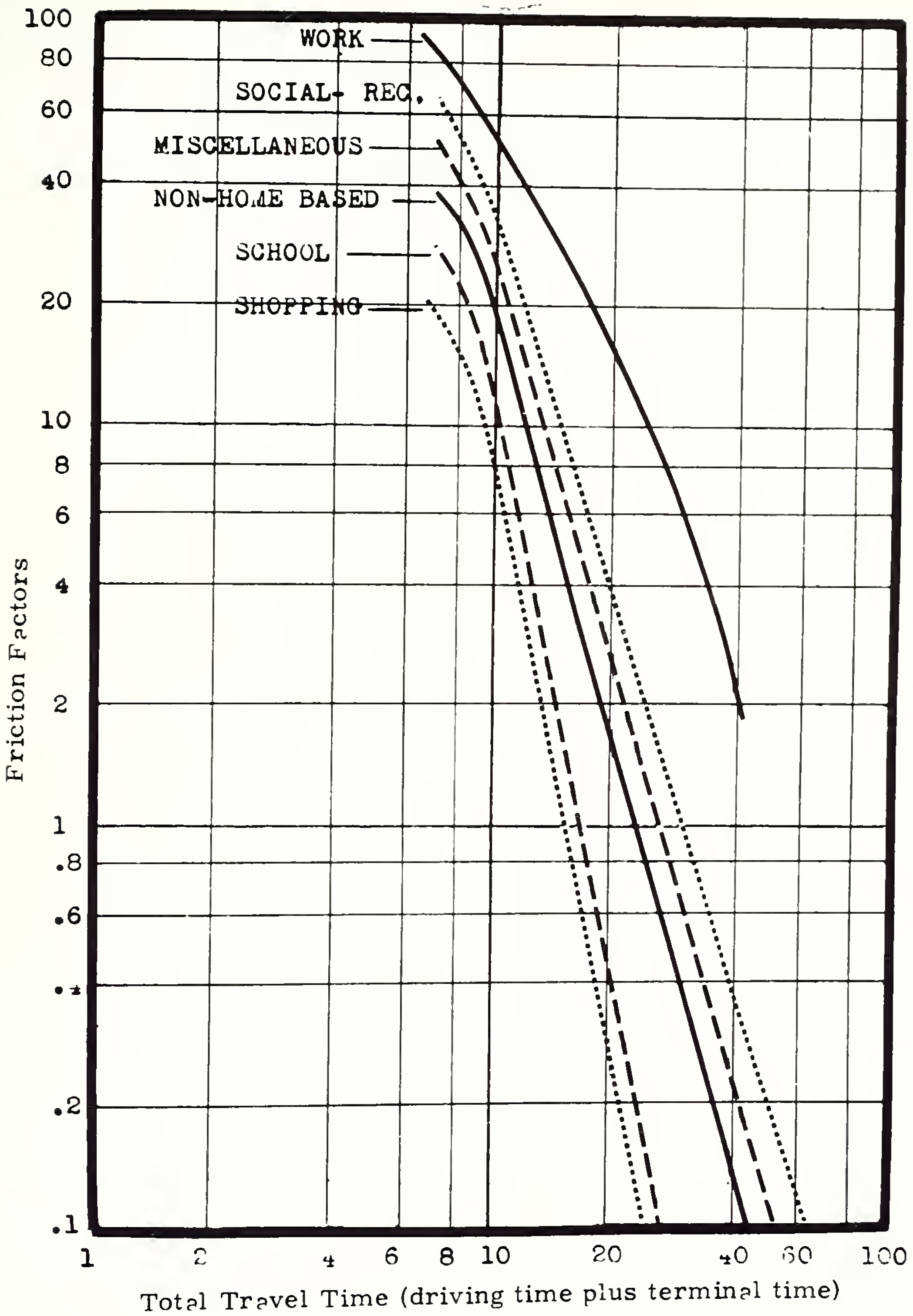
Table 3

Characteristic of trips produced in a residential area

Purpose of trip	Measure of Attraction	Distance parameter
Work	No. of workers employed	$D^{\frac{1}{2}}$
Social	Dwelling units	D^3
shopping convenience goods	Floor Area in foods & drugs	D^3
shopping goods	Floor Area in apparel	D^2
business	(1)	(1)
recreational	(1)	(1)
other	(1)	(1)

(1) These trips should be considered as shopping good trips.

With wide use of the model for predicting trip patterns, it was found that the exponent in the equation seemed to vary with the travel time. This was most pronounced for work trips however, the trips for the remaining purposes could be approximated by a constant exponent although there was considerable deviation at the shorter travel times (12). This is shown by figure 1 where the friction factor F is equal to the travel time raised to a power: $F = D^x$.



Friction factors, Washington, D. C., 1955.

FIGURE I

A new form of the gravity model was subsequently prepared that would account for this deviation in the travel time exponent. The modified model appeared in the form:

$$T_{i-j} = \frac{P_i A_j F_{d_{i-j}} K_{i-j}}{\sum_{\substack{k=1 \\ k \neq i}}^{n} A_k F_{d_{i-k}} K_{i-k}}$$

where: T_{i-j} = trips from i to j

$F_{d_{i-j}}$ = an emperically determined set of friction factors

K_{i-j} = a specific zone-to-zone adjustment factor to allow for the effect of social-economic interaction

P_i = trips produced by zone i

A_j = attraction of zone j

This new form of the model was more flexible and facilitated computation, in addition to eliminating the exponent associated with the travel time (12).

To use the model, the friction factor F, and the social-economic factor K have to be determined, using either information from a previous O-D study or a small sample home-interview study. Trips are first stratified by purpose and a model for each purpose is then calibrated. Calibration of the friction factors is done first, with the social economic factor K assumed to be equal to one.

Initially, the F values are set equal to one and a distribution is made using the known trip production and attractions. A frequency distribution of trips versus travel time in discrete time intervals (usually one half or one minute) for the synthesizied trips is prepared. A similar distribution is also prepared for the actual trip interchangs. Comparison of the two curves is done and F values are selected that will cause the synthezied curve to closely approximate the actual frequency distribution. The distribution is repeated with the new friction factors and a similar comparison is made. The above technique follows the recommendation of the Bureau of Public Roads Gravity Model Manual (12). Iterations are continued until the ratio of the present friction factor to the previous friction factor approaches unity. After the friction factors have been calibrated, a table is prepared with unique friction factors for each trip purpose.

Determination of the social economic K factor is done for each zonal interchange (i-j) for each trip purpose. The K is a value which causes the predicted trip interchanges from the friction factor calibration to equal the actual interchanges.

The computation form is:

$$K_{i-j} = \left(\frac{T_{i-j}}{T'_{i-j}}\right)\left(\frac{1-\frac{T'_{ij}}{T_i}}{1-\frac{T_{ij}}{T_i}}\right)$$

where: K_{i-j} = social economic factor for i-j

T_{i-j} = trips from i to j from previous O-D study

T'_{i-j} = trips predicted in friction factor calibration

T_i = total trips produced in zone i

When all friction factors and special economic factors have been determined for each trip purpose, the model is calibrated and ready to use to predict zonal interchanges for the various trip purposes.

Whiteside and Roberts have attempted a further development in the refinement of the gravity model, which they call a sector gravity model (33). Their model is of the form:

$$T_{i-j} = \frac{P_i A_j F_{(t_{i-j})}}{\sum_{x=1}^{n} A_X F_{(t_{i-x})}}$$

where: T_{i-j} = trips produced in zone i and attracted to zone j

P_i = trips attracted by zone j

$F_{(t_{i-j})}$ = empirically derived distribution factor related to the time separation between zones i and j

As in the standard form of the gravity model, trips are stratified by purpose for distribution. The unique features of this model is that the urban area can be divided

up into as many as six different sectors based on social-economic, geographic, topographic, or political criteria. There is no limitation on the way in which the sectors are prepared except that there must not be more than six. Calibration of the model involves determining the distribution factors $(F_{t_{i-j}})$ for each sector and trip purpose.

Another difference in the sector model as compared with the standard model is that the production and attraction in each zone must be predicted before the model can be used to predict future travel patterns. These predicted trips ends are used as control factors in the final distribution for each model.

To perform the final distribution, the calibrated model distributes trips to each attraction zone. Because the model has a tendency to over and under distribute trips, an iterative process is necessary, using the predicted productions and attractions as controls. First the trips produced from each zone are summed and compared to the control trip ends. The individual assignments are then balanced by the factor A, where A equals the control total divided by the production total for zone i from the distribution. This is done for each production zone. When this has been accomplished the same is done for each attraction zone factoring each individual attraction zone by the factor B, where B equals the control attraction of zone divided by the sum of the attracted trips by zone i from the distribution.

The productions are then checked against the control total and the iterative process is continued until 90 percent of the balancing factors lie between 0.95 and 1.05. To date, the sector model has seen limited applications.

The following is a list of some of the advantages and disadvantages of the gravity model (20).

Advantages:

1. The primary advantage of the gravity model is that it accounts for competition for trips between different land uses.
2. It is sensitive to changes in travel time between zones.
3. It is easy to understand, and therefore, easy to apply in any particular urban area.
4. It is relatively inexpensive, since it requires little travel inventory information (i.e., it does not require a complete home interview O-D survey to provide necessary input data).
5. It recognizes trip purpose as affecting zonal interchange.

Disadvantages:

1. The main weakness of the gravity model is the attempted application of a simple physical law (i.e., Newton's Law of Gravitation) to social behavior while apparent similarities do exist, a more fundamental procedure related to human behavior is needed.
2. An average travel pattern cannot be applied to all zones within the urban area, since there is considerable variation in the social and economic characteristics of zonal populations.
3. Trip length distributions (by purpose) do not remain constant throughout the urban area. Therefore, the exponent of distance is not necessarily constant from place to place, from time to time, or over an unlimited or undefined

range of distance. This was time of the original form of the model.

4. The changing nature of distance (in terms of travel resistance) between zones with time of day makes questionable the use of a single value of travel time, regardless of the transportation facilities available.

5. As the distance between zonal-centroids decreases to zero, the number of trips predicted between two zones becomes infinitely large. Although the interzone distance will not be zero in practice, an excessive number of trips may be predicted when centroids are very close together.

6. The model tends to show only approximate agreement with field data when the zones and cumulative traffic volumes are small.

7. The gravity model requires a considerable manipulation of proportionality factors in order produce result comparable to observed traffic patterns.

Previous research

Brokke and Mertz conducted a study to evaluate growth factor methods of distribution. They compared distributions using the uniform factor, average factor, Detroit, and Fratar growth factor method. To control the effect of the growth factor, the growth factor were determined by comparing trip ends in corresponding zones from origin and destination studies conducted in 1948 and 1955 in Washington, D.C.

The findings of their study indicated that the Fratar method arrived at the final distribution in fewer iterations than the Detroit, Average factor and uniform factor. The Detroit was the next preferred method, and due

to the iterative nature of the models, they all arrived at similar answers given enough time. Another outgrowth of the study was the fact that considerable variability arose in zones with few trip ends causing a high root mean square error (1).

A comparative evaluation of trip distribution models was performed by Heanne and Pyers of the Bureau of Public Roads (14). They attempted a comparative analysis of the Fratar technique, the Gravity Model, the opportunity model, and Tomazinis' competing opportunity model in Washington, D.C. To minimize the effect of trip end predictions on the models, two origin and destination studies, one conducted in 1948, the other conducted in 1955 were used to determine growth factors and future trip ends. The ratio of the 1955 to 1948 trip ends for each purpose in the different study zones produced the growth to be used in the Fratar distribution. Production and attractions for the Gravity Model and the inputs to the opportunity model and competing opportunities model were taken directly from the 1948 and 1955 O-D study.

Calibration of the three interarea models was done using the 1948 information and checked using the four following criteria:

1. Ability to match trip length frequency distribution from the O-D survey.
2. Ability to produce river crossing volumes that match O-D survey volumes.

3. Ability to match O-D survey trip movements by corridor to and from the CBD.

4. Accuracy of model as measured by statistical comparison of O-D survey and model of trips assigned to a spiderweb networks.

Difficulty was encountered in calibration of the competing opportunities model and as a result only the Fratar, Gravity, and opportunity models were compared.

After calibration, trip interchange were predicted by three methods for 1955. An analysis of these prediction was performed using the above four criteria. As a result of their study, Heanne and Pyers concluded that:

1. The gravity and the intervening opportunities models proved about equal reliability and utility in simulating the trips for the two years in the study area.

2. The Fratar Growth Factor procedure showed a good ability to correctly expand trips for stable areas but showed significant weakness in predicting interchange in zones undergoing land use changes.

3. The competing opportunity model was found difficult to calibrate using small study zones.

DESCRIPTION OF STUDY AREA

The city of Lafayette, Indiana was selected as the study area for evaluation of updating techniques for two reasons:

1) an O-D study had been conducted in the area which would provide a base for the investigation;

2) Purdue University is located in the Greater Lafayette area which enabled the researcher to become familiar with different characteristics of the city and also facilitated data collection.

The greater Lafayette area is located in the Wabash River Valley in Tippecanoe County in the northwestern portion of the state of Indiana. The City of Lafayette was first platted in 1826 and incorporated in 1856 while West Lafayette which makes up the rest of the metropolitan area was started in the late 1880's and incorporated in 1924.

Because of its favorable location, the Lafayette area has evolved into a dominant agriculture, education, industrial, and cultural center of Northern Central Indiana. Purdue University located in West Lafayette has helped

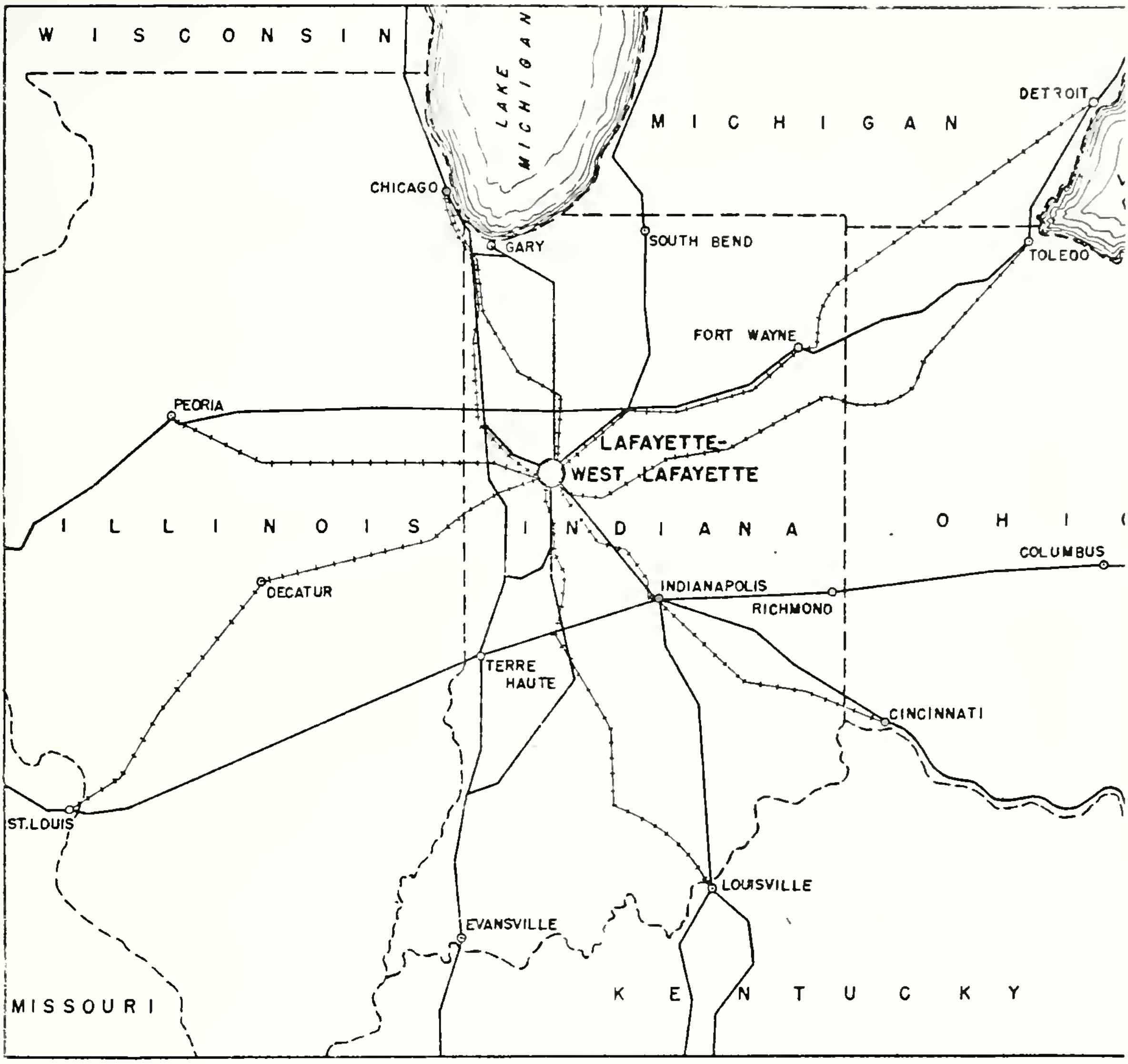
spread the influence of the area throughout the state and has provided a major source of income for the area.

Heavy industry, along with the newer clean industries, are well represented in the Lafayette area, providing a broad economic base.

With respect to transportation, the Lafayette area is well located, being readily accessible by highway, railroads, and air. State Roads 25, 26, 38, and 43 and U.S. 52 cross the city and provide connections with the surrounding communities, in addition to placing the city on the main route between the north central midwest and the southeastern portions of the United States, see figure 2. The city is served by the New York Central Railroad, the Monon Railroad and both the Nickle Plate and Wabash lines of the Norfolk and Western Railroad. In addition to this, commercial flights to Purdue Airport are provided by Lake Central Airlines.

Metropolitan Planning has long been active in the area, with the first comprehensive plan for development of the area prepared in 1928. At the present time, planning for the metropolitan area and the remaining areas of Tippecanoe County is the responsibility of Area Plan Commission. Purdue University has adhered closely to a development program which was formulated in 1924.

On August 22, 1950, a traffic study was authorized for the Lafayette area by the State Highway Commission of



LAFAYETTE-WEST LAFAYETTE INDIANA
LOCATION AND TRANSPORTATION CONNECTIONS

FIGURE 2

of Indiana. The study was begun in September, 1952 by state highway personnel with assistance from the Bureau of Public Roads, the Joint Highway Research Project and civic and governmental leaders of Lafayette and West Lafayette. An abbreviated final report of the findings was issued in late 1964. The population at the time of the study authorization was 49,441 and by 1960 had increased to 55,010. In addition to this the enrollment at Purdue University has increased from 9,739 students in 1953 to 18,710 students in 1964.

DEVELOPMENT OF DISTRIBUTION MODELS AND TRIP PURPOSE

Distribution models

A shortcoming of the growth factor distribution technique has been the inability to include new or additional O-D zones in the study area for updating or predicting future design year travel patterns. This has limited the use of these distribution techniques to updating base studies that are relatively recent, usually no more than five years old. The five year span is considered short enough so that the effect of rapid growth is minimized and that reasonable growth factors can be obtained for the unstable or changing zones. In addition to this, the short time differential from the base study should reduce the chances of new zones being included in the total study area. Because of the chance of new zones being required twenty-five to thirty years after the base study, great difficulty has arisen in using the growth factor distribution techniques to predict the future travel patterns, although projections have been made for the Detroit and Cleveland metropolitan areas using these methods (8,10). Attempts have been made to modify the growth factor method so that new zones could be included and one technique has been developed which has received use by at least one group

in their work (24).

The Lafayette study was begun in 1952 and a period of twelve years had lapsed before the update evaluation study was undertaken in the fall of 1964. Considerable growth had occurred during the twelve year span which necessitated the addition of new zones and the subdivision of several of the larger original zones which had shown rapid growth in different land uses. To include the use of the growth factor distribution methods, a modification of these original models was required.

The development of the modified Fratar method begins with an analysis of the original equation. The future trips from zone i to zone j is a function of the base year trips from zone i to zone j and the growth factors of zones i and j.

$$T_{i \rightarrow j} = \left(t_{ij} \cdot F_i \cdot F_j\right) \Bigg/ \left(\frac{\sum_{k=1}^{n} t_{ik}}{\sum_{k=1}^{n} F_k \cdot T_{ik}} \right)$$

$$T_{j \rightarrow i} = \left(t_{ji} \cdot F_j \cdot F_i\right) \Bigg/ \left(\frac{\sum_{k=1}^{n} t_{jk}}{\sum_{k=1}^{n} F_k \cdot t_{jk}} \right)$$

$$L_i = \frac{\sum_{k=1}^{n} t_{ik}}{\sum_{k=1}^{n} t_{ik} \cdot F_k}$$

$$L_j = \frac{\sum_{k=1}^{n} t_{jk}}{\sum_{k=1}^{n} t_{jk} \cdot F_k}$$

$$T_{ij} = \left(\frac{T_{i\to j} + T_{j\to i}}{2}\right) = \left(t_{ij}\cdot F_i\cdot F_j\cdot L_i + t_{ji}\cdot F_j\cdot F_i\cdot L_j\right)$$

$$T_{ij} = \left(t_{ij}\cdot F_i\cdot F_j\right)\left(\frac{L_i + L_j}{2}\right)$$

Where $T_{i\to j}$ = trips from i to j

$T_{j\to i}$ = trips from j to i

F_i = growth factor for zone i

F_j = growth factor for zone j

t_{ik} = base year trips between zone i and zone k

T_{ij} = total number of two directional trips between i and j

After all trips have been distributed the predicted trip ends in the zone all are calculated.

$$T_i' = \sum_{j=1}^{n} T_{ij}$$

These are then compared with the total estimated trip ends (T_i) which have been determined before hand and a computation factor F_i' computed for each zone

$$F_i' = \frac{T_i}{T_i'}$$

When the factor approaches one, the distributions have been made.

Considering a new zone, where no trip interchanges existed between that zone and any other zone in the base year, the t_{ij} value is zero. If the zero value of this term were to be used in computing both L_i and T_i', they would always be zero and no trips would be distributed to the new zones. Consider the value of the future trip ends T_i. In many growth factor methods, this value is obtained from the product of the growth factor F_i and the base year trips t_i, the growth factor having been determined by direct factor techniques. Even if the zone is new, direct factor techniques can be used to determine a growth factor (this will be explained under growth factor determination procedure) but because the value of t_i is zero, the product of $F_i t_i$ will always be zero.

The first problem approached was that of future zonal trip ends. Using the growth factor predicted will always result in zero future trip ends. To circumvent this, trip ends were predicted by an independent method which could either be regression analysis or land use generation procedures. The regression equations are developed from the base year study and measured or estimated values for the zone variables are input, to produce the future trip ends. Land use generation methods will employ

generation rates based on zones of similar social, economic and physical characteristics. The trip ends, which are predicted for the new zone, will be used as the control value in the computation of the iteration factor F_i'.

For the first iteration, the L_i parameters for the base year study zones are to be calculated using only the original zone values for t_{ij} and the growth factor F_i for the respective zones. This computation will yield values of zero for the parameter L_i for each of the new zone and some value greater than zero for the original zones. To provide for non-zero trips between the new zones and all other zones, an initial value of 0.01 is given to each L_i (new). A problem still remains because all t_{ij}'s for the new zones are non existant. This computational problem is handled by assigning each t_{ij} (new), an initial value of 0.01. Once non-zero values have been assigned to each of the parameters, the first approximation of interzonal trips for all zone combinations is calculated. This first series of calculations will produce numerical values greater than zero for all parameters in the model and enables the use of the standard Fratar procedure for all further calculations. The second and subsequent iterations are continued until the computational factors approach unity. The method is

illustrated by an example problem in Appendix A.

The Detroit Model, being similar in nature to the Fratar Model, experiences the same drawbacks. To facilitate the use of the Detroit Model for any study area, a technique for modifying the model was developed. Since the model closely resembles the Fratar Model, the derivation of the modified Detroit Model follow closely that of the Fratar. To develop the modified Detroit procedure, the variables in the model must be understood. The model is:

$$T_{ij} = \left(t_{ij}\right)\left(\frac{G_i G_j}{G}\right)$$

where: T_{ij} = predicted trips between i and j

t_{ij} = base year trips between i and j

G_i = growth factor of zone i for first iteration and the computation factor for succeeding iterating

G = area growth factor for first iteration and computation factor for succeeding information

The growth factors for all zones, both original and new, can be computed by any of several techniques. As in the modified Fratar, future trip ends for all new zones are predicted independently of the growth factors and these become control values in the calculations of the computational factors for all iterations after the first. To handle the situation of zero zonal interchanges, an initial

value of 0.01 is given to each zero t_{ij}. The area growth factor for the first iteration is calculated using the total trip ends predicted for the future as determined from the original and new study zones and the total trips from the base year study. All iterations after the first, follow the standard Detroit model procedure. An illustrated example of the method is shown in Appendix B.

The modified growth factor models distribute trips according to the pull of the zones with upper limits on the computational factor determined from the future trip ends.

With this modification, growth factor models may be applied to almost any urban area regardless of the rate of growth and the addition of new zones.

Trip purpose synthesis

The gravity model technique is based on distributing two way trips between production and attraction zones or in some recent studies, between origins and destinations (21). Generally, the approach taken is to call all trips that begin or end at the trip makers home, productions and all other terminals, attractions. These are referred to as home based trips and usually range from 80 to 90 percent of all internal trips in the study area. The balance of the trips in the area are referred to as non-home based trips. Distribution of these trips is done in a different manner than the home based trips. Origins of the trips are considered as the productions while the destinations are considered as attractions. Further refinements of the production and attractions have resulted in stratifying home based and non-home based trips into trip purpose in order to increase the accuracy of distribution. Typical stratification is:

1. Home Based
    - a.) Home to Work
    - b.) Home to Shopping
    - c.) Home to Business
    - d.) Home to Social Recreation
    - e.) Home to Other
2. Non-Home Based
    - a.) Work to Shopping
    - b.) Work to Social-Recreational
    - c.) Work to Other
    - d.) Shopping to Social-Recreational
    - e.) Shopping to Other
    - f.) Business to Work
    - g.) Business to Shopping
    - h.) Business to Other

Many transportation studies done in the early 1950's did not classify trips as to purpose, only reporting the total zonal interchanges. With trips reported in this form, there is no idea of productions and attractions which complicates the use of the gravity model for distribution.

The researcher desired to include the gravity model in the evaluation but to do this, some measure of the productions and attractions in each origin-destination zone was necessary. It was decided that a synthethic distribution of zone trips could produce reasonable values of productions and attractions in each zone. Based on theo-

TABLE 4

HOME-BASED TRIPS BY URBAN RESIDENTS IN STUDY AREAS ACCORDING TO PURPOSE[1] (29A)

URBAN AREA	HOME-BASED TRIPS AS PER CENT OF ALL LINKED TRIPS	PER CENT OF HOME-BASED TRIPS TO AND FROM: WORK	BUSINESS	SHOPPING	SOCIAL RECREATIONAL	SCHOOL	OTHER	ALL PURPOSES	TOTAL HOME-BASED TRIPS PER DWELLING UNIT
Chicago[2]	86.8	37.5	9.7	18.9	22.8	4.0	7.1	100.0	5.17
Detroit	87.0	41.6	8.6	13.9	20.1	6.3	9.5	100.0	4.67
Washington	91.6	43.1	9.6	14.2	12.5	9.4	11.2	100.0	4.23
Pittsburgh[2]	87.0	37.7	21.6	14.9	13.8	12.0	---[3]	100.0	4.21
St. Louis	91.3	37.5	8.1	17.3	21.5	6.4	9.2	100.0	4.90
Houston	91.0	33.1	8.9	17.3	18.6	10.8	11.3	100.0	5.51
Kansas City	88.2	33.4	8.8	17.2	22.7	6.0	11.9	100.0	5.14
Phoenix	85.3	25.2	10.2	19.7	20.0	11.6	13.3	100.0	4.76
Nashville	85.5	30.3	8.5	16.9	23.9	7.4	13.0	100.0	5.48
Ft. Lauderdale	86.5	27.9	15.3	24.0	22.9	0.9	9.0	100.0	2.82
Charlotte	83.6	32.2	8.0	15.6	23.8	6.6	13.8	100.0	2.82
Reno	86.5	29.2	12.7	18.1	26.3	0.5	13.2	100.0	4.88
Avg. Per Cent	87.6	34.0	10.8	17.4	20.8	6.8	10.2	100.0	4.78[4]

---

[1] Source: Origin-destination studies in each area.

[2] Chicago and Pittsburgh data are for "linked" trips.

[3] All trips in Pittsburgh have been identified with one of the listed purposes.

[4] Unweighted average.

retical approach, a technique for estimating productions and attractions from total zonal trip ends was developed.

The major premise for synthetic stratification is that there is no significant statistical variation in the percentage of home based trips in different cities. In addition to this, it was hypothesized that the percentage of home based work trips, home based shopping trips, home based social-recreational trips, and home based other trips did not vary from city to city.

To support this hypothesis, information from table 4 was statistically analyzed by means of an analysis of variance test. After discussion with the statistical consultant, the cities in table 4 were grouped into 5 classes of two each, based on city size. The city of Pittsburgh was eliminated because the information was not comparable, and the city of Charlotte was deleated by a random process to provide two cities in the 0 - 250,000 population range. The classification of the cities was as follows:

Class I - population greater than 2,000,000
Class II - population range 1,000,000 to 2,000,000
Class III - population range 1,500,000 to 1,000,000
Class IV - population range 250,000 - 500,000
Class V - population range 0 - 250,000

The final tabular forms for the analysis are shown in tables 5 and 6.

TABLE 5

Percentage of Home based Trips of Total Trips

CLASS	CITY	% OF HOME BASED TRIPS
I	Chicago	86.8
	Detroit	87.0
II	Washington	91.6
	St. Louis	91.3
III	Houston	91.0
	Kansas City	88.2
IV	Phoenix	85.3
	Nashville	85.5
V	Fort Lauderdale	86.5
	Reno	86.5

TABLE 6

PERCENTAGE OF HOME BASED TRIPS BY PURPOSE

CLASS	CITY	WORK	BUSINESS	SHOPPING	SOL.REC.	SCHOOL	OTHER
I	Chicago	37.5	9.7	18.9	22.8	4.0	7.1
	Detroit	41.6	8.6	13.9	20.1	6.3	9.5
II	Washington	43.1	9.6	14.2	12.5	9.4	11.2
	St. Louis	37.5	8.1	17.3	21.5	6.4	9.2
III	Houston	33.1	8.9	17.3	18.6	10.8	11.3
	Kansas City	33.4	8.8	17.2	22.7	6.0	11.9
IV	Phoenix	25.2	10.2	19.7	20.0	11.6	13.3
	Nashville	30.3	8.5	16.9	23.9	7.4	13.0
V	Ft. Lauderdale	27.9	15.3	24.0	22.9	0.9	9.0
	Reno	29.2	12.7	18.1	26.3	0.5	13.2

Analysis was first performed on the percent of the total trips that are home based, using a one way analysis of variance test. Because the percentage values in table 5 follow a binomial distribution, the mean and variance not being independent of one another, it was necessary to perform an arcsine square root transformation on the data (22). The transformation is of the form:

$$Y = \text{arcsine}\sqrt{\text{percentage}}$$

The null hypothesis for this analysis was that the percentage distribution of home based trips was the same in each city. The value of the F ratio calculated was 0.001. At an alpha of 5% with 4 and 5 degrees of freedom, the tabular F is 5.19, therefore the null hypothesis was accepted.

For the analysis of the percentage distribution of the home based trips by purpose, a two way analysis of variance was performed on table 6 with six levels of variable one, trip purpose, and 5 levels of varible two, city size. Again, the data had to be transformed by an arcsine square root transformation. Actual computation was done on a digital computor using a "canned program", the BIMD 2V program, written by the U.C.L.A. Health Sciences Computing Facility. The null hypothesis for this analysis was:

1.) There are a significant differences between the distribution of trip purposes.

2.) There are no significant differences in the distribution of trips by purpose with different city size.

3.) There are no interactions between trip distributions by purpose and size of city.

A value of 12.039 was the calculated F ratio for the comparison of different trip purposes. At an alpha level of 5 percent and 5 and 30 degrees of freedom the tabular F value is 2.05 which resulted in the acceptance of the null hypothesis. For the analysis of trip distribution by city size, the calculated F ratio was 1.120 compared with a tabular F of 2.14 at 4 and 30 degrees of freedom at an alpha of 5 percent. Hence, the null hypothesis was accepted. The analysis of the interaction produced an F of 1.166 versus tabular F of 1.67 at an alpha of 5 percent with 20 and 30 degrees of freedom, which indicates no significant interaction.

In summary then, there appears to be no effect of city size on the percentage of home based trips of total trips in the urban area. The distribution of home based trips by purpose in the different cities are statistically the same, while the percentage of trips for each purpose are statistically different. In addition to this, there appears to be no effect of city size on trip purpose distributions.

With this information, it is now possible to determine average percentage values for home based trips and the distribution of these trips by purpose. Since the analyzed values are statistically similar, an arithmetic average will yield these average values. Table 7 shows

the average values determined from the analysis.

Table 7

Average Percent of Home Based Trip

Classification	Percent
Total Home Base	87.97
Home Base by Purpose	
Work	33.88
Shopping	17.75
Business	10.04
Other	38.33

To break down total trip ends in a zone, the urban area must be classified by land use type. Once this has been done, the average values are applied to each zonal trip total to produce productions and attractions. By performing this synthesize, the gravity model can be used to determine trip patterns.

PROCEDURE

Selection of the study area

In the early 1950's a series of traffic surveys were conducted in several cities in the state of Indiana by the Metropolitan Area Traffic Survey Unit of the Indiana State Highway Commission. Among these cities were the cities of Lafayette and West Lafayette (17). It was decided to select the city of Lafayette as the city in which

the evaluation study was to be conducted because of its close proximity to Purdue University and because it was one of the more comprehensive studies done at that time.

The study conducted in the fall of 1952 was of the post card interview type. Post cards had been mailed to all owners of registered vehicles in this study area, requesting a list of their daily vehicle trips. Response to the questionnaire resulted in a return of 40% and this was considered adequate for this type of technique. Using suitable factors, the sample was expanded to produce an estimate of total daily interzonal movement.

There had been no attempt to stratify trips according to trip purpose, nor had there been an attempt to relate trips to land use except in a few instances. Trips to Purdue University, Aluminum Corporation of America, CBD Zones, and several selected industrial zones along U.S. 52 Bypass were identified and listed accordingly. Other than this group, there was no corelation of trips to land use or trips to purpose.

Virtually all data collected for the study and the study work sheets were kept on file in the Department of Planning, Indiana State Highway Commission, State Office Building, Indianapolis, Indiana. The availability of the data in its original form greatly facilitated work on the update evaluation study.

Determining origin and destination zones

Between the time of the original study in 1952 and the update evaluation study in 1964, considerable growth had occurred in the greater Lafayette area. This was especially true of locations both to the north and south of the U.S. 52 Bypass in the City of West Lafayette and to the area along the bypass in Lafayette. In addition to this, large residential subdivisions known as the Tecumseh subdivision and Edgelea subdivision had been developed to the south of the city of Lafayette. During the twelve year time span, decentralization of the commercial area away from the central business district had occurred. During that time, six shopping centers had been built, ranging in size from neighborhood centers to a large community shopping center, with two of the centers in West Lafayette, the remaining four in Lafayette.

To account for this growth and to include it in the study area, new O-D zones were created. In the original 1952 study there was a total of seventy-five zones, twenty-four in West Lafayette and fifty-one in Lafayette. For the updating techniques study, thirty-one additional zones were created, thirteen in West Lafayette and eighteen in Lafayette. The total number of zones in the evaluation

study area was one hundred and six.

New zones were added in two ways; addition of complete new areas, and subdivision of the original zones into smaller zones based on differential land use development. In both cases the criteria used for the delimitation of the zones were homogeneity of land use type, topography, and man made features such as highways and railroads. To gain a good understanding of the environmental features of a particular area in question, several trips were made to the area to provide a first hand account.

In addition to this, use was made of aerial photographs. Photographs taken for the United States Department of Agriculture in 1952 were useful in ascertaining the type, location, and intensity of land use development at the time of the original traffic survey. This was an aid in the subdivision of some of the larger original zones. Areas of sparse development in 1952 that had differing land use development in 1964 were partitioned and made into new zones on the basis of homogeneous land use. Boundaries for these zones were determined either from man made or physical barriers. Actual determination of these boundaries was facilitated through the use of stereoscipic pairs of aerial photographs of the area taken for the United States Department of Agriculture in 1962. The new zones created by subdivision of the old zones lie wholly within the original study area and show the effect of major land use changes within that

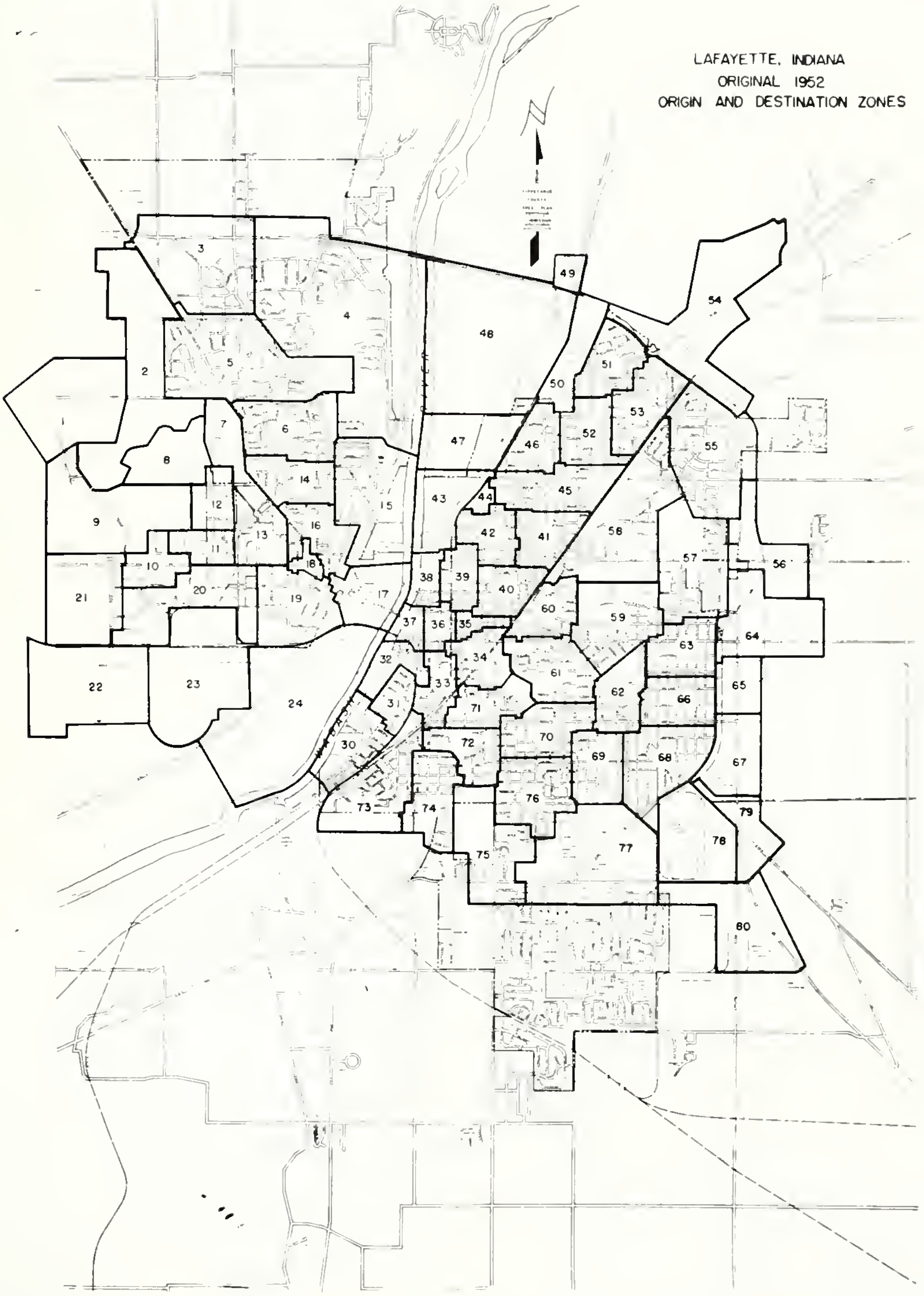

LAFAYETTE, INDIANA
ORIGINAL 1952
ORIGIN AND DESTINATION ZONES
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FIGURE 3

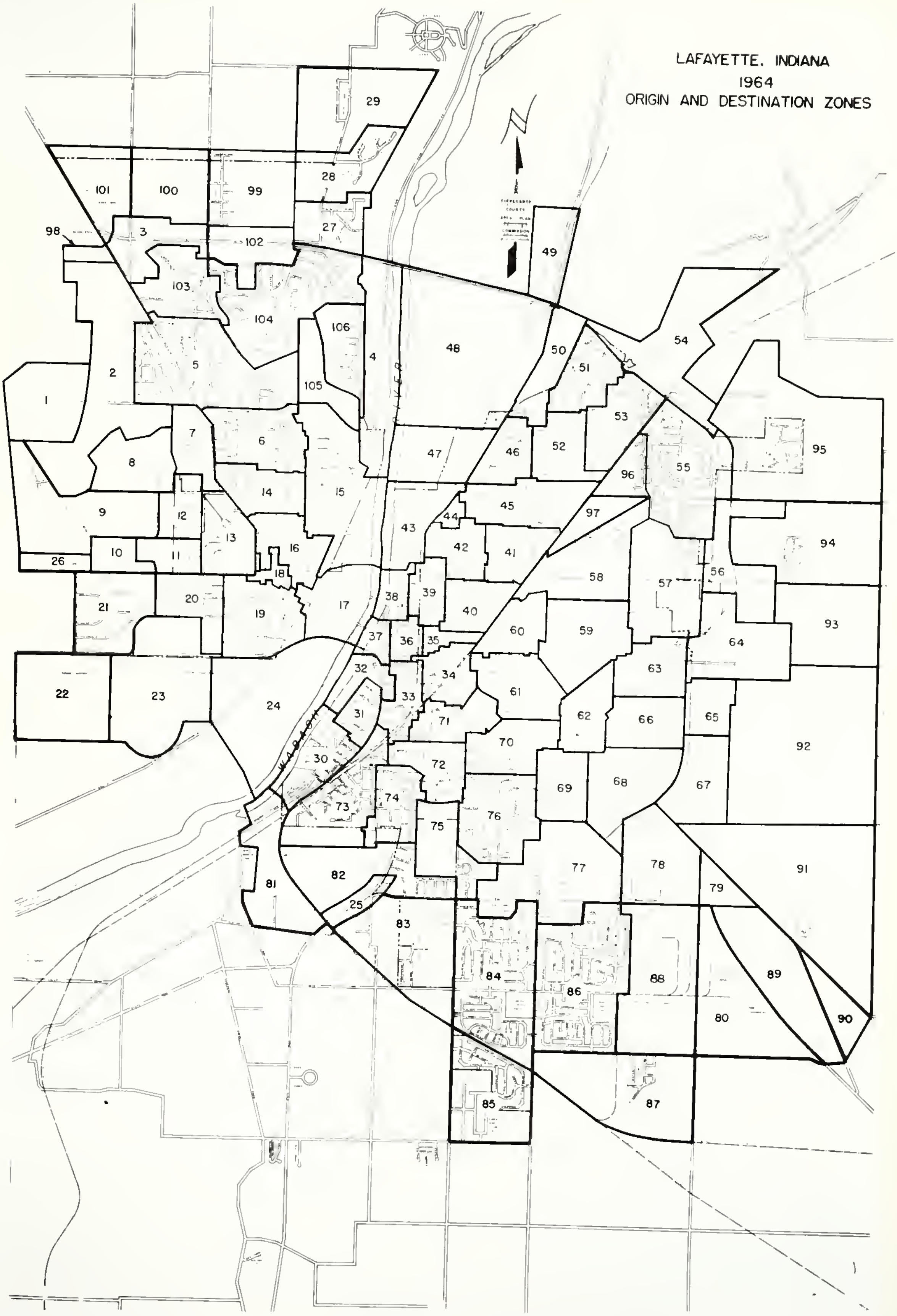
LAFAYETTE, INDIANA
1964
ORIGIN AND DESTINATION ZONES
RIVER
WABASH
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FIGURE 3A

area.

The completely new zones were created to include development which had taken place along the perimeter of the area, especially to the north in West Lafayette and to the east and south in Lafayette. Homogeniety of land use within a particular zone was one basis for determining the zones. Other factors considered were topographic and man made physical barriers. It was also the desire of the researcher to create zones that would be able to include future land use development of a single land use type. First hand knowledge of all the new areas was gained through numerous trips through these areas. Maps of proposed future land use development were obtained from the Tippecance County Area Plan Commission. Stereoscopic pairs of aerial photographs taken in 1962 were also used in the zone area determination. The resulting zones that were created using the above information were, in the opinion of the researcher, fairly uniform in land use type, able to account for future growth, described by well defined boundaries, and susceptable to the use of certain study techniques.

Selection of trip generation and trip distribution techniques

The evaluation study could be separated into two distinct phases, that of determining future zonal trip ends and growth factors and determining the interzonal trip interchanges. Much thought was given to the selection of the meth-

area.

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Selection of trip generation and trip distribution techniques

The evaluation study could be separated into two distinct phases, that of determining future zonal trip ends and growth factors and determining the interzonal trip interchanges. Much thought was given to the selection of the meth-

ods to be studied and the final selection was based on the information available from the 1952 traffic study and the existance and availability of certain input data.

For the study of trip generations and growth factor prediction, regression analysis, land use generation, and direct factor techniques were considered. Since the original survey made no attempt to correlate trips with land use on an area basis and since a detailed land use map was not available for 1952, land use generations methods could not be used. It was therefore decided to limit the trip generation-growth factor phase of the study to regression analysis and direct factor techniques.

The trip distribution phase of the study was confined to the investigation of the Fratar Growth Factor method, the Detroit Growth Factor method and the Gravity Model. Originally it was thought to include the Opportunity Model in the study but the lack of comprehensive trip and land use data necessary for the calibration of the model excluded the model. Two other growth factor techniques, the Uniform Factor method and the Average Factor method, were given some consideration but were eliminated on the findings of Brokke and Mertz (1).

The final selection of techniques for the study included regression analysis and direct factor techniques for trip end prediction and the Detroit method, the Fratar method and the Gravity Model for trip distribution. Each

of the growth factor distribution models was used with all the methods of trip end prediction while only the regression analysis was combined with the gravity model.

Selection of variables and inputs to the models

After reviewing previous research in the field, it was felt that only a few variables need be studied for trip prediction. These were considered in light of the ease of obtaining the required data and the time required to collect this data. The final selection of variables consisted of the following six: 1.) population; 2.) dwelling units; 3.) automobile registration; 4.) number of employees; 5.) number of commercial and industrial establishments; 6.) Purdue University student enrollment.

The variables were grouped according to land use and applied in the respective zones. This required stratifying the study zones by land use type, into residential, commercial, industrial, recreational, and institutional.

Population, dwelling units, and automobile registration were regarded as good predictions of trip generation in the zones deemed residential. The measure of trip generations potential in the industrial areas were considered as a function of the number of employees and the number of establishments. For commercial zones, employees and establishments were also considered as adequate measures. Purdue University was regarded as institutional and the

number of employees and students was regarded as indicative of the trip potential. No information could be obtained for recreational zones and it was decided to apply a factor reflecting growth in the demand for recreational facilities that had been determined elsewhere.

Division of study zones by land use

To enable a better prediction of growth in the study area, it was decided to segregate the study zones by land use type. It was felt that certain variables if grouped according to their related land use would yield growth factors that were more representative of the zone rather than applying all the factors. In addition to this, the stratifications enabled a more objective use of the regression analysis. The stratification produced five different land use types, residential, commercial, industrial, institutional (Purdue University), and recreational (Purdue Golf Courses and Happy Hollow Park in West Lafayette).

The procedure for the stratification was based on the principal of predominant land use type. Since only a general land use map was available for 1952 (17), the assignment of land use to a zone was determined by the major land use indicated by the land use map. Generally the land use chosen for the zone constituted ninety percent of the particular land use within the zone.

The stratification process was divided into three

phases; unchanged original zones, subdivided original zones, and new zones. Land use allocation to the original study zones was entirely by the predominantly land use techniques. Subdivision of the original zones was based entirely on a uniform land use resulting in the predominant land use being nearly 100% of the assigned land use. The new zones had been established with the criteria of homogenity of land use so that like the subdivided zones their predominant land use was almost 100% of the assigned land use. The final division of zones into predominant land use resulted in sixty-eight zones termed residential, fifteen zones termed commercial, eighteen zones termed industrial, three zones termed institutional, and two zones termed recreational.

Street code

In order to assign the collected values for the different variables, it was necessary to prepare a street code which gave the zone location of each street or street segment in the study area.

A street code existed from the 1952 study and was used as a base in the preparation of the 1964 street code. Street zone breakdowns in the 1952 street code were checked against changes in the 1964 street system and corrections were made. Adjustments were made for streets in the subdivided zones. Changes in street names over the twelve year span were accounted for and corrections were made

accordingly.

The streets in the new zones and new streets in the original zones posed a somewhat different problem. Using the urban street map of the greater Lafayette area prepared by the Tippecanoe County Area Plan Commission, all streets within the new zones and all new streets in the old zones were listed by zone. Breakdown of the streets into segments of the streets within a particular zone was accomplished by using the plat map with street numbers of the area kept in the city engineers office in the cities of Lafayette and West Lafayette.

A problem was encountered in determing the street segmentation in those zones lying outside the city limits of West Lafayette and Lafayette. This problem was overcome by the generous help of the Assistant Postmaster of Lafayette who had independently prepared a street numbering system of the unincorporated areas surrounding the two cities. The final street code contained the segmentation of all streets by zone in both the incorporated and unincorporated parts of the study area.

In its final form, the street code gave the section of each street by street address included in each zone.

Data collection

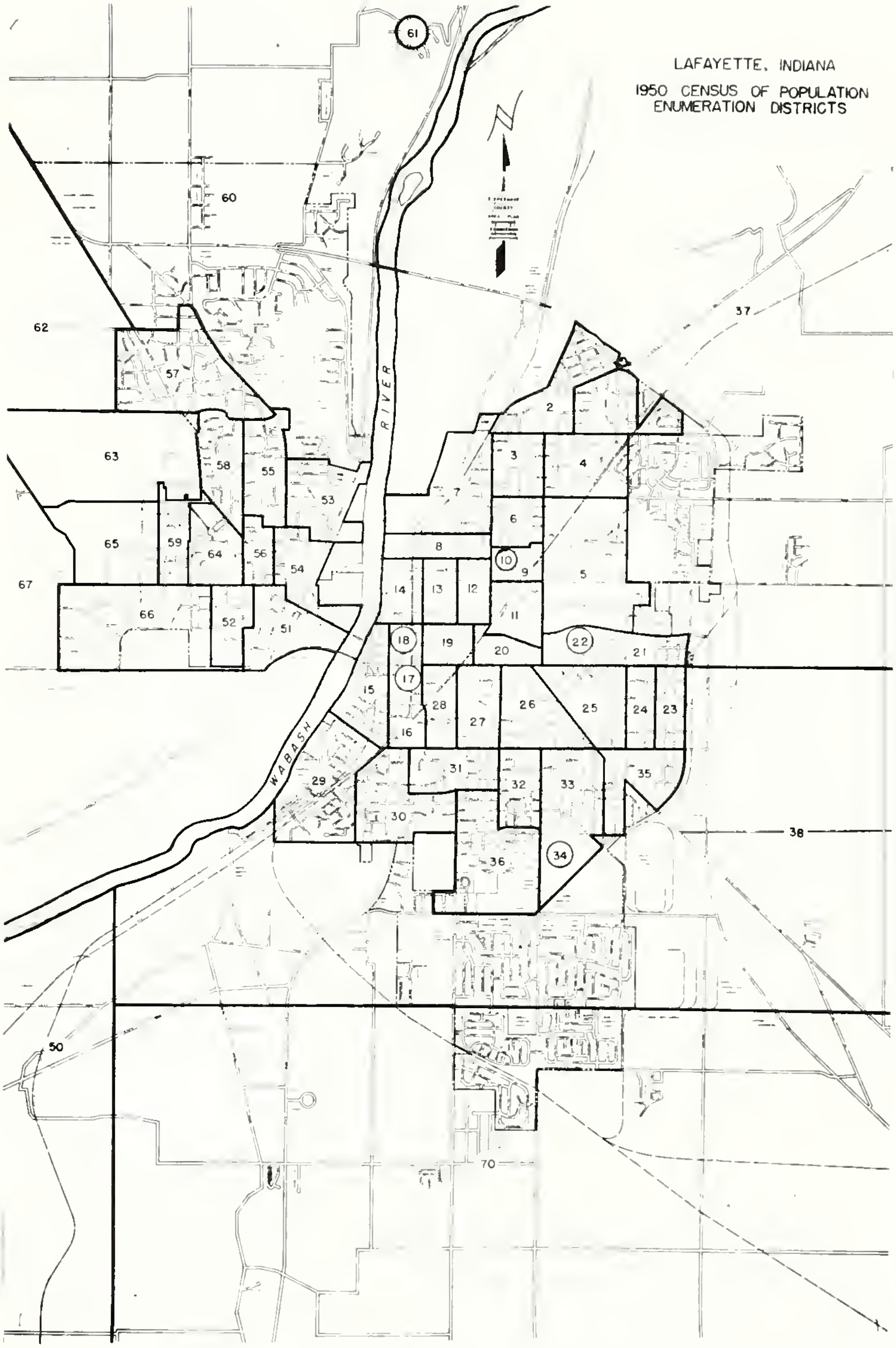
The collection of data centered on the six variables, population, dwelling units, automobile registration,

commercial and industrial employees, commercial and industrial establishments, and enrollment and employment at Purdue University. In order to determine growth in trip generation and 1964 trip ends in the study zones, data were collected for the base year and the update year. All data variable collection was keyed to and dependent on the street code, with the exception of population.

Population

Population for the zones was determined using the 1950 and 1960 reports of the U.S. Department of Commerce, Bureau of the Census. Maps of the enumeration districts and the PH-1 forms corresponding to the district were obtained for each of the two years. On observation, it was noticed that in general, the enumeration districts did not correspond to the transportation study zones. Furthermore, it was also observed that the enumeration districts were different for the two year.

Because there was no apparent direct coorelation between the census enumeration districts and the transportation study zones, it was decided to proportion the population of each district according to the study zones. Separate proportional breakdowns were prepared for both 1950 and 1960 and the population of each zone was determined accordingly.


LAFAYETTE, INDIANA
1950 CENSUS OF POPULATION
ENUMERATION DISTRICTS
N
RIVER
WABASH
61
60
37
62
57
2
63
58
55
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4
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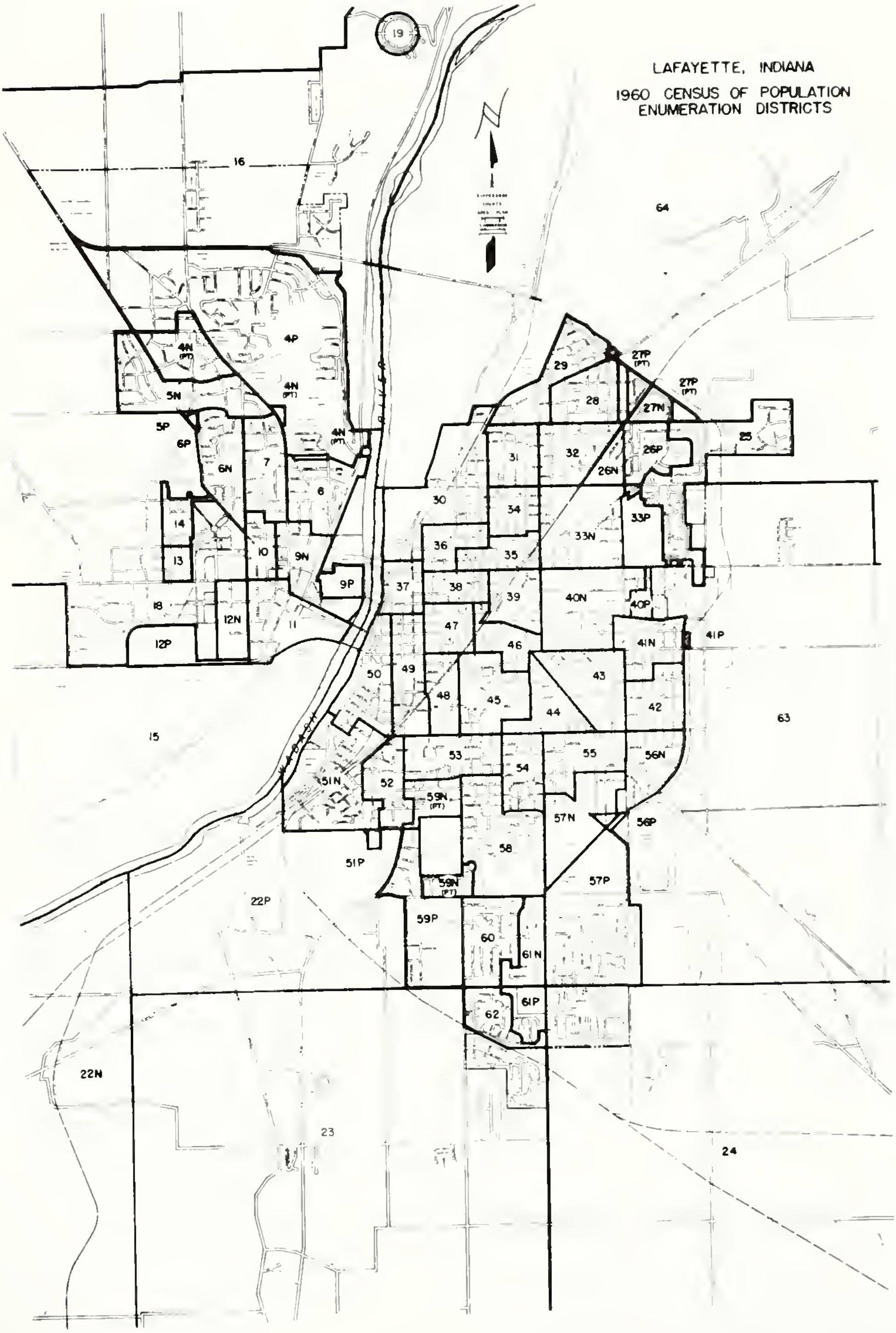
FIGURE 4


LAFAYETTE, INDIANA
1960 CENSUS OF POPULATION
ENUMERATION DISTRICTS
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19
16
64
WABASH
RIVER
4N (PT)
4P
5N
4N (PT)
5P
6P
4N (PT)
6N
7
6
14
13
10
9N
9P
18
12N
11
12P
15
29
27P (PT)
27P (PT)
28
27N
25
31
32
26N
26P
30
34
33P
33N
36
35
37
38
39
40N
40P
47
41N
41P
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43
44
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63
53
55
56N
54
51N
52
59N (PT)
57N
56P
58
51P
59N (PT)
57P
22P
59P
60
61N
61P
62
22N
23
24

FIGURE 5

Dwelling units

The number of dwelling units in each study zone for 1952 and 1964 was obtained from the Lafayette City Directory for those years. Each listing of a residence and each listing of an individual apartment were considered as dwelling units. The listing of residences by street was compared to the street code to provide a breakdown of the dwelling units by study zones for the two year.

Automobile registration

Automobile registration was desired for the two years 1952 and 1964. On investigating, it was found that automobile registration records were only available back to 1956. The data collection was then confined to 1956 and 1964.

The 1956 records were kept on microfilm in the Cash Audit Section of the Department of Motor Vehicles, State of Indiana in the State Office Building, Indianapolis, Indiana. These records were read in coordination with the street code, and each registered vehicle was assigned to its respective zone. For the collection of 1964 vehicle registrations, a listing for all motor vehicles registered in Tippecanoe County, Indiana was obtained from the Credit

Bureau of Lafayette. These listings were read in a similar manner as the 1956 records and zone totals were obtained for vehicle registration.

Commercial and industrial employees and establishments

The Lafayette City Directory and records from the Indiana Employment Security Division were utilized in the collection of information on employees and establishments. A listing of all the commercial and industrial establishments was prepared for 1952 and 1964 using the city directory for those respective years and the street code. This listing was prepared for only those zones deemed industrial and commercial in the land use stratification. The resulting totals gave the number of establishments in the zones for each of the two years.

Once the number and identity of establishments in the zones had been determined, then number of employees for each establishment was assigned from records made available by the Indiana Employment Securities Division. These records gave employment by firm for all firms employing four or more people. Not all firms were listed on these records. To complete the employee listing, average employment figures for each type of establishment were used. This was done for the two years in question. Totals were then obtained for employment in industrial and commercial zones for 1952 and 1964.

Purdue University

Information on employment and enrollment for the two study years was obtained by personal correspondence with the Business Office and the Registrars Office of Purdue University.

Supplementary information

Information for the 1952 study was provided from records compiled by the Indiana State Highway Commission in the "Lafayette-West Lafayette Indiana Traffic Survey Report"(17). Land use information for the present year and plans for future area development were obtained from "A Summary of the Comprehension Plan for: Lafayette, West Lafayette and Tippecanoe County, Indiana" (30A). Travel time information for present travel times was obtained from "Early Impact of A Highway Improvement in an Urban Area", by A. F. Lohr (18).

Growth factor determination and future zonal trip ends

Determination of growth in the study zones was performed using two techniques, regression analysis and direct factor methods. As previously discussed, the zones in the study area had been segregated according to predominant

land use type. Each technique was applied to the different land use types under the theory that the appropriate variables would be the best indicators of growth in the zone.

Regression analysis

The regression analysis was performed using trip ends and variables from 1952 to establish the prediction equation. To put all zones on a comparable basis, trip ends and values of the variables were transformed to a rate per acre. All of the regression equations were determined by means of a "build up" regression computer program (BIMD -2R). Once the equation had been established, 1952 and 1964 trips were predicted from the value of the variable from 1952 and 1964. The ratio of the 1964 predicted trip ends to the 1952 predicted trip ends produced the growth factor for the zone.

A total of thirty-four residential zones were used to determine the prediction equation for residential trips. The variables that were correlated with residential zone trip ends were population density, dwelling units, density and automobile density.

Industrial trips were estimated by correlating the number of employees with trips in the zone. Sixteen industrial zones were used for the determination.

For the commercial trip prediction, values from nine zones were used. A correlation between trips and

number of employees and number of establishments was made.

It was not possible to establish regression equations for institutional and recreational zones because of the small amount of data sets. Growth factors for these zones were arrived at using direct factor techniques.

The growth factors calculated by regression techniques for residential, commercial, and industrial zones were combined with direct factors obtained for institutional and recreational zones to produce one set of growth factors. From here on, these growth factors will be referred to as growth factor by method three.

Direct factor methods

Direct factor methods have been treated in two ways, interaction method and arithmetic average method. Growth factors computed by these methods will be referred to respectively as growth factor method one and growth factor method two. In both methods, as in the regression analysis, the zones were treated on a stratified basis.

Growth factor one method (interaction)

The interaction method of calculating growth factors is based on the premise that the factors affecting trip generation reinforce each other. In other words, one factor directly influences another in a multiplier effect causing a greater total effect. Residential zone growth factors were determined using the variables, population, dwelling

units, and automobile registration. The form for this expression is:

$$\text{Residential Growth Factor} = \left(\frac{\text{1960 pop.}}{\text{1950 pop.}}\right)\left(\frac{\text{1964 DU.}}{\text{1952 DU.}}\right)\left(\frac{\text{1964 Auto. Reg.}}{\text{1956 Auto. Reg.}}\right)$$

Growth factors for industrial and commercial zones were calculated in the same way using number of employees and number of establishments in the zone. This equation took the form:

$$\text{Industrial Growth Factor} = \left(\frac{\text{1964 Employees}}{\text{1952 Employees}}\right)\left(\frac{\text{1964 Establishments}}{\text{1952 Establishments}}\right)$$

$$\text{Commercial Growth Factor} = \left(\frac{\text{1964 Employees}}{\text{1952 Employees}}\right)\left(\frac{\text{1964 Establishments}}{\text{1952 Establishments}}\right)$$

Direct factor growth factors for recreational and institutional zones were combined with these growth factors to produce the set of growth factors by method one.

Growth factor two method. (arithmetic average)

In this method, it was assumed that each variable contributed equally to the growth in trip production. No multiplier effect is produced and each variable is considered independent of the other.

Residential growth factors were determined using the three variables, population, automobile registration, and dwelling units. This expression is:

$$\text{Residential Growth Factor} = \frac{\left(\frac{\text{1960 pop.}}{\text{1950 pop.}}\right) + \left(\frac{\text{1964 Auto.Reg.}}{\text{1956 Auto. Reg.}}\right) + \left(\frac{\text{1964 DU.}}{\text{1952 DU.}}\right)}{3}$$

Commercial and industrial growth factors were computed by averaging the number of employees and number of establishments. The equations are:

$$\text{Industrial Growth Factor} = \frac{\left(\frac{\text{1964 Employees}}{\text{1952 Employees}}\right) + \left(\frac{\text{1964 Establishments}}{\text{1952 Establishments}}\right)}{2}$$

$$\text{Commercial Growth Factor} = \frac{\left(\frac{\text{1964 Employees}}{\text{1952 Employees}}\right) + \left(\frac{\text{1964 Establishments}}{\text{1952 Establishments}}\right)}{2}$$

Direct factor growth factor for recreational and institutional areas were combined to yield the set of growth factors by method two.

Institutional (Purdue University) growth factors were calculated from the 1952 and 1964 employment and student enrollment figure for the school. This technique was straight forward and the growth factor calculated was included in methods one, two, and three. The expression is:

$$\text{Institution Growth Factor} = \left(\frac{\text{1964 Employment + Enrollment}}{\text{1952 Employment + Enrollment}}\right)$$

There was no way in which a growth factor could be calculated for recreational zones because of the difficulty in obtaining data. Because of this, a growth factor that was indicative of the general increased usage of recreational land was used.

In all cases of direct factor methods, care had to

taken in the computation of the individual growth factors for the five variables. There were instances where there was no value for a variable for 1952. When such cases arose, a value of one was introduced to replace the zero value. This enabled the calculation of a non-infinite growth factor.

Distribution techniques

The evaluation study, as mentioned previously, included two growth factor distribution model and the Gravity Model. The growth factor models were combined with the three methods of growth factor prediction resulting in six different trip distributions. To handle zones in which no trip had existed in 1952, the modified growth factor distribution had been developed. In the use of the gravity model, only the regression technique could be used to predict 1964 trip ends because of many zones with no 1952 trips. The distribution phase was a comparison between seven prediction-distribution techniques, six growth factor procedures and the gravity model.

The growth factor distributions were relatively straight forward. Computer programs were written for the Modified Detroit and the Modified Fratar methods and the actual computations were done on the IBM 7094 computer at the Computer Sciences Center, Purdue University.

The gravity model, however, posed a somewhat

different problem. Because the original traffic survey had not stratified trips by purpose, it was difficult to directly apply the gravity model. For this reason, synthesis of trip purpose was attempted and average percentage values of trip purpose breakdown were developed.

In order to use the gravity model, these average percentage values had to be used to convert the total area trips into production and attraction.

The gravity model requires calibration before it can be used to distribute trips. In many instances a small sample is used for calibration, in others a previous origin destination study is used for the calibration. For application in the updating evaluation study, it was required that the model be calibrated on the 1952 study. As a result, the first synthesis of trip purposes was for the 1952 trips.

Average percentage values of trips by purpose had been found independent of the size of the city (refer to table 5). The procedure that was used to distribute trips according to purpose, and production and attractions in Lafayette for use in the gravity model calibration was the following:

1. Determination of home base productions
    a.) All home based trips are in residential zones.

    b.) Percent of trips in residential zones which are home based production.

        1) Total trips in Lafayette = 89,312

2) Total trip ends in Lafayette = 2x89,312 = 178,624

3) Total trip ends in residental zones = 112,095

4) Total home based trips = $\left(\frac{87.97}{2}\right)(178,624)$ = 78,577

5) Percent of total trips in residential zones which are home based = $\frac{78,577}{112,095}$ =70.10%

6) Percent of home based trips which are work production = (33.88%)(70.10%) = 23.75%

7) Percent of home based trips which are business productions = (10.04%)(70.10%)= 7.04%

8) Percent of home based trips which are shopping productions = (17.75%)(70.10%) = 12.44%

9) Percent of home based commercial trips = shopping trips + business trips = 7.04% + 12.44% = 19.48%

10) Percent of home based other trips = (38.33%)(70.10%) = 26.87%

2. Total Residential Attractions = 100% - 70.10% = 29.90%

3. Determination of work trip attractions

a.) Total work trip attractions = (23.75%) (112,095) = 26,623

b.) All trip ends in institutional zones (Purdue University) are for the purpose of work

1. Total work trips in institutional zones = 16,749

2. Percent of trip ends in institutional zones which are work trip attractions = 100%

c.) Total work trips attractions in industrial and commercial zones = 26,623 - 16,749 = 9,874

d.) Distribute work trips to industrial and commercial zones based on number of employees

1. Number of employees in commercial zones = 7,101

2.) Number of employees in industrial zones = 8,725

3.) Percent of employees in commercial zones = $\frac{7{,}101}{7{,}101 + 8{,}725} = 44.87\%$

4.) Percent of employees in industrial zones = $\frac{8{,}725}{7{,}101 + 8{,}725} = 55.13\%$

5.) Number of work trip attraction in commercial zones = (44.89%) (9,874) = 4,430

6.) Number of work trip attractions in industrial zones = (55.13% (9,874) = 5,444

7.) Total number of trip ends in commercial zones = 35,328

8.) Total number of trip ends in industrial zones = 14,349

9.) Percent of work trip attractions in commercial zones = $\frac{4{,}430}{35{,}328} = 12.54\%$

10.) Percent of work trip attractions in industrial zones = $\frac{5{,}444}{14{,}349} = 37.94\%$

4. Determination of Commercial Trip Attractions

a.) Number of Commercial trip productions

1) Number of shopping trip productions = (12.44) (112,095) = 13,945

2) Number of business trip productions = (7.04) (112,095) = 7,811

b.) Assign all shopping trips to commercial zones = 13,945

c.) Distribute business trips according to number of establishments

1) Number of establishments in commercial zones = 811

2) Number of establishments in industrial zones = 128

3) Percent of establishments in commercial zones = $\frac{811}{128 + 811} = 86.37\%$

4) Percent of establishments in industrial zones = $\frac{128}{128 + 811} = 13.63\%$

5) Number of business trip attraction in commercial zones = (86.37%) (7,811) = 6,815

6) Number of business trip attractions in industrial zones = (13.63%) (7,811) = 1,076

d.) Commercial trips equal shopping trips plus business trips
   1) Total commercial trips in commercial zones = 13,945 + 6,815 + 20,260
   2) Total commercial trip ends in industrial zones = 1,076 + 0 = 1,076
   3) Percent of trip ends in commercial zone which are commercial trip attractions = $\frac{20,260}{35,328}$ = 57.35%
   4) Percent of trip ends in industrial zones which are commercial trip attractions = $\frac{1,076}{14,349}$ = 7.50%

5. Distribution of home based other trips
   a.) Distribute attractions according to total trip ends
      1) Percent of industrial zone trips of total trips = $\frac{14,349}{161,772}$ = 8.87%
      2) Percent of commercial zone trips of total trips $\frac{35,328}{161,772}$ = 21.84%
      3) Number of home produced attractions = (26.87%) (112,095) - recreational production = 30,120 - 99 = 30,021
      4) Number of industrial zone other attractions = (8.87%) (30,021) = 2,663
      5) Number of commercial zone other attractions = (21.84%) (30,021) = 6,557
      6) Percent of industrial trips which are other attractions = $\frac{2,663}{14,349}$ = 18.56%
      7) Percent of commercial zone trips which are other attractions = $\frac{6,557}{35,328}$ = 18.56%

6. Distribution of non-home based other trips
   a.) Assume all non-home based other trips are to residential zones from industrial and commercial zones.
   b.) Determine non-home based other production
      1) Percent of industrial zone trips which are non-home based other productions = 100% - (37.94% + 7.50% + 18.56%) = 36%
      2) Percent of commercial zone trips which are non-home based other production = 100% - (12.54% - 57.35% - 18.56%)= 11.55%

3) Number of non-home based productions from industrial zones = (36%)(14,349) = 5,166

4) Number of non-home productions from commercial zones = (11.55%) (35,328) = 4,080

c.) Determine residential zone attractions for non-home based trips
  1) Total attraction = 5,166 + 4,080 = 9,246
  2) Percent of residential zone trips which are non-home based attractions = $\frac{9,246}{112,095}$ = 8.25%

7. Recreational Trips
  a.) All recreational trips are attracted in recreational zones
    1) Number of recreational attractions = 99
  b.) Number of residential produced recreational trips = 99
    1) Percent of produced trips = $\frac{99}{112,095}$ = 99

8. Residential zone home based other trip other attractions = 100% - (23.75% + 19.48% + 0.09% + 26.76% + 8.25%) = 21.67%

Summary of distribution of trips by purpose, productions and attractions in Lafayette

Residential Zones:
- A. Home based productions 70.10%
  - 1. To work 23.75%
  - 2. To commercial 19.48%
  - 3. To recreational 0.09%
  - 4. To other (Industrial, commercial) 8.21%
  - 5. To other (residential) 18.55%
- B. Attractions 29.90%
  - 1. Home based other 8.23%
  - 2. Non home based other 21.67%

Commercial Zones:
- A. Non-home based production
  - 1. Other to residential 11.45%
- B. Attractions
  - 1. Home based work 12.54%
  - 2. Home based commercial 57.35%
  - 3. Home based other 18.56%

Industrial Zones:	
A. Non-home based productions	
1. Other to residential	36.00%
B. Attractions	
1. Home based work	37.44%
2. Home based commercial	7.50%
3. Home based other	18.56%
Institutional Zones:	
A. Productions	0%
B. Attractions	
1. Home based work	100.00%
2. Gravity Model calibration	
Recreational Zones:	
A. Productions	0%
B. Attractions	100.00%

The form of the gravity model that was used is the one that is currently recommended by the Bureau of Public Roads and is given by the expression:

$$T_{ij} = \frac{\dfrac{P_i A_j}{(K_{ij})(F_{ij})}}{\displaystyle\sum_{e=1}^{n} \frac{A_e}{(K_{ie})(F_{ie})}}$$

Where: T_{ij} = trips from zone i to zone j

P_i = production of zone i for a trip purpose

A_j = attraction of zone j for that trip purpose

A_e = attraction of remaining zones i = 1-n

F_{ij} = friction factor related to travel time between zones i and j

K_{ij} = social-economic factor effecting trips between zones

The percentage values for production and attraction were applied to all zonal trips based on their respective

land use. The results of this operation gave the number of productions and attractions in each zone according to trip purpose. In addition to this, the trip interchanges between zones were determined for each trip purpose.

Actual calibration of the model to determine the travel time factors and the social-economic factors was done according to the Bureau of Public Roads procedure for the calibration of the gravity model. In order that the calibration could be done in the manner prescribed, travel times had to be obtained.

A travel time contour map from the 1952 study was used to determine interzonal travel times. Centroids were located in each of the 106 zones. The technique used for locating centroids was to assume that there was a uniform distribution of activity in each zone. With this assumption, the zone was treated as a plane and the zone centroid was located at the geometric center. Travel times were measured to each nearest neighbor centroid surrounding the centroid in question. This was done for all 106 zone centroids, plus three bridges. In addition to this, terminal times were added to the link times. A value of $1\frac{1}{2}$ minutes was used for residential zones, 4 minutes for commercial zones, and 2 minutes for industrial and institutional zones. Since recreational zones were not considered in the distribution zero times were used. All river crossings were required to be by one of the three bridges that existed in

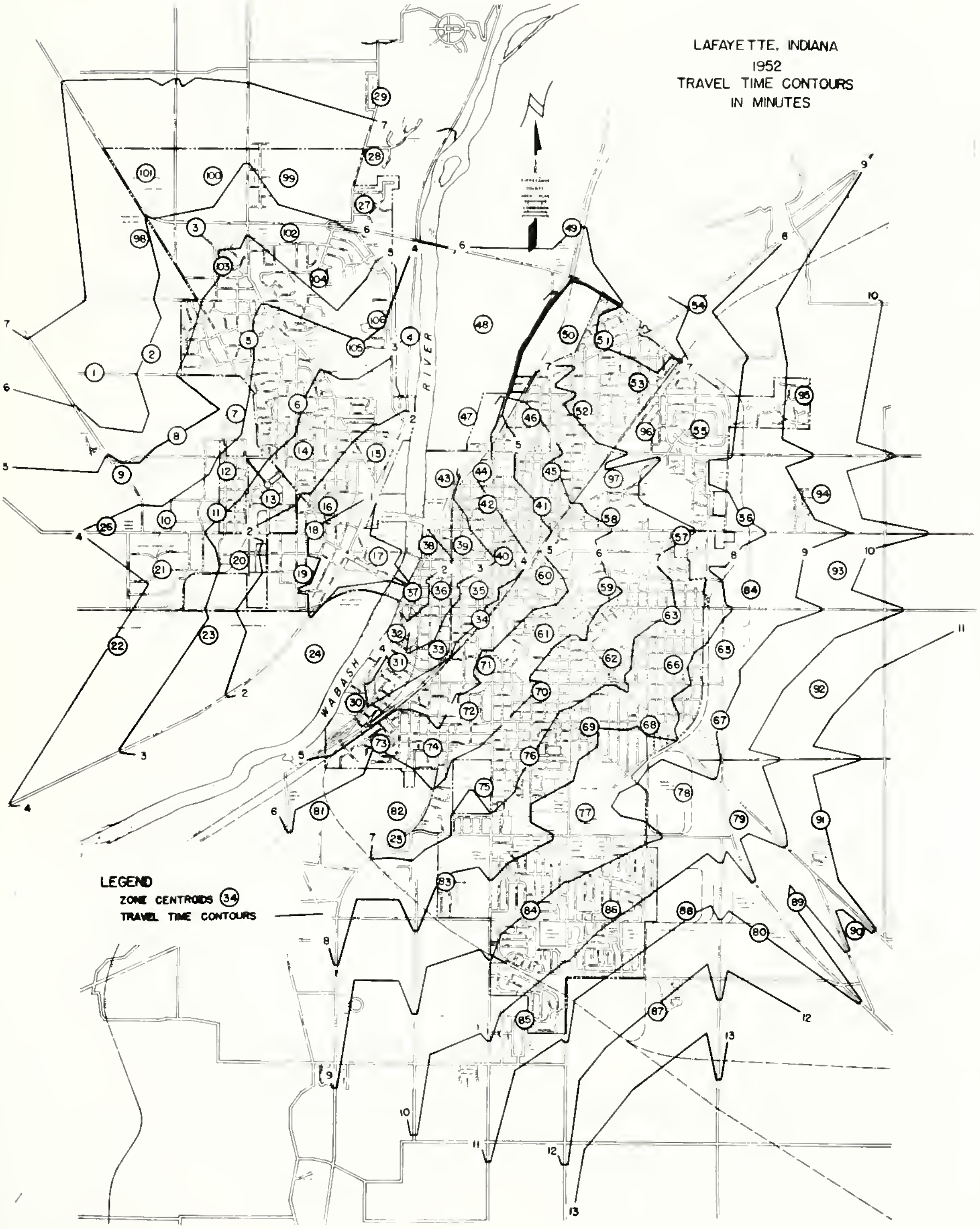

LAFAYETTE, INDIANA
1952
TRAVEL TIME CONTOURS
IN MINUTES
LEGEND
ZONE CENTROIDS (34)
TRAVEL TIME CONTOURS
WABASH
RIVER

FIGURE 6

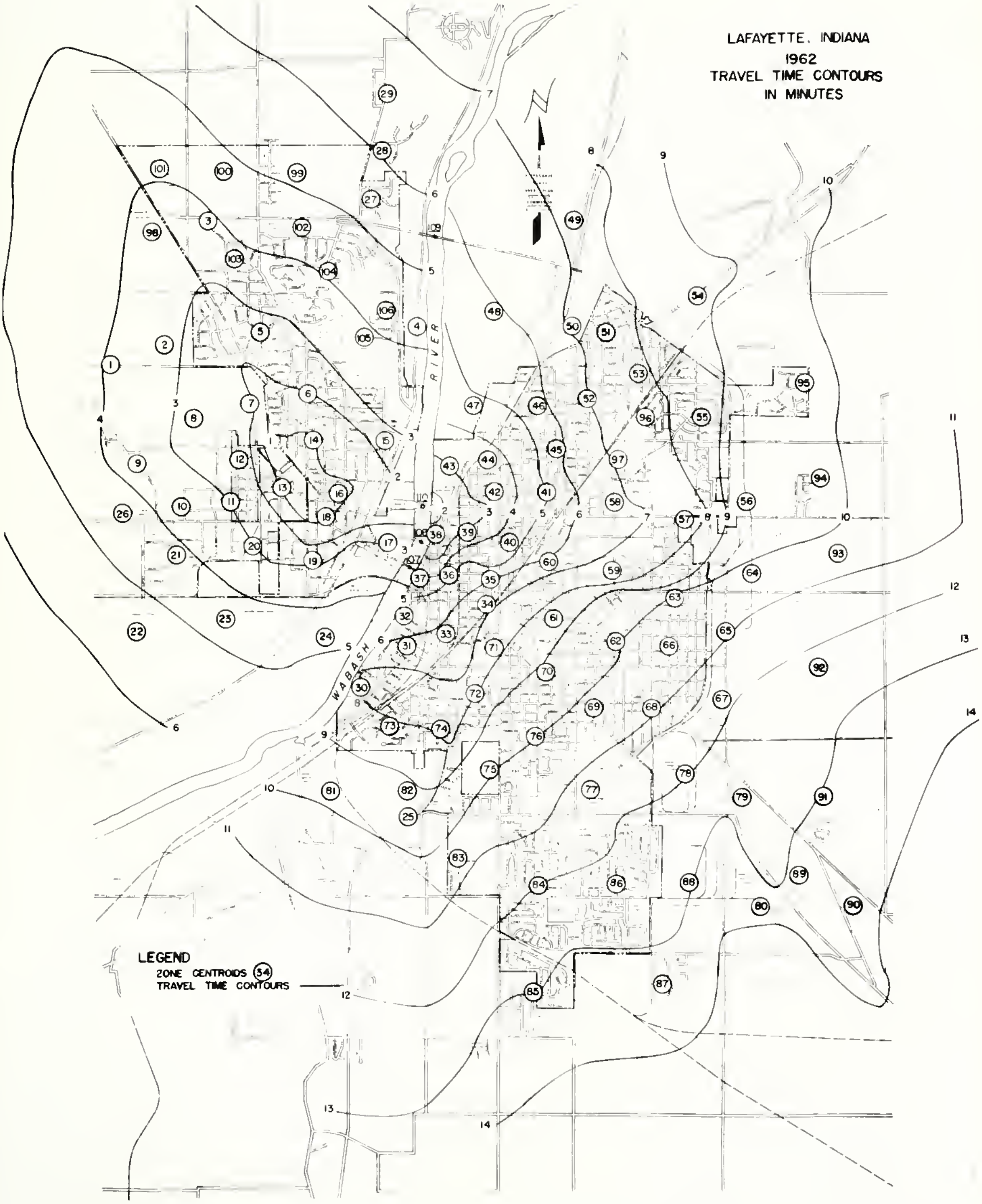

LAFAYETTE, INDIANA
1962
TRAVEL TIME CONTOURS
IN MINUTES
LEGEND
ZONE CENTROIDS (34)
TRAVEL TIME CONTOURS
WABASH
RIVER

FIGURE 7

1952. A minimum path program that produced travel times between all zonal combinations was written for the IBM 7094 computer.

Actual calibration was done for each trip purpose using the productions and attractions determined synthetically. Comparison was made with the trip interchange determined for each purpose and travel time. Four calibration routines were required to determine the set of friction factors "F" and the social-economic factors "K" for each trip purpose. It was decided not to distribute recreational trips because of their small number.

Distribution of 1964 trips by the gravity model was done by first applying the percentage values determined for production and attractions for each trip purpose by zone land use type. To determine which friction factor should be used for a particular zonal interchange for the trip purpose in question, a new set of zonal travel times was calculated. The procedure for this was similar to the calculation of the 1952 travel times. A travel time contour map was obtained for 1962 (18). It was assumed that travel times had not changed much in the two years between 1962 and 1964. This was based on the fact that no major road improvements or construction of major traffic generation had occurred in that time span. The nearest neighbor method was used to determine travel time links. Travel times between all zonal combinations were obtained from the

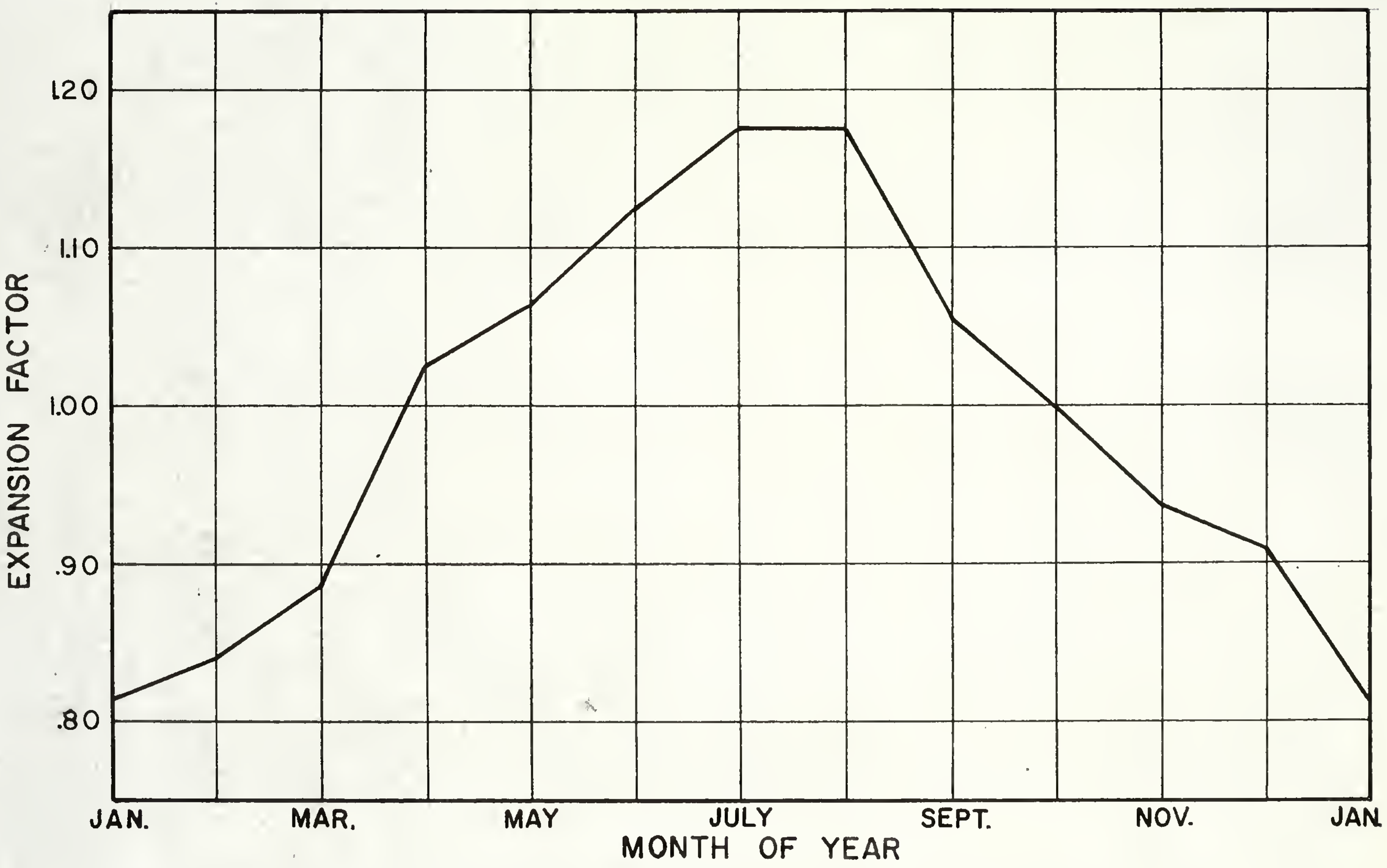
minimum path computer program. The same values of terminal times for the different land uses established for 1952 were used for the 1962 computation. A total of 106 zones and four bridges were included in this analysis. Friction factors were determined for all zone combinations, even those including the new zones.

The social-economic factor "K" posed a somewhat different problem. For all the original zones, "K" values existed for the four trip purposes distributed. No "K" values existed for interchanges between any paired combination containing a new zone. To circumvent this, a "K" value of one was assumed.

A total of four distributions was made for the study area, one for each purpose. All four resulting trip tables were superimposed on each other to produce total predicted trip distributions for the study area.

Varification counting

The original study plan called for comparison of the Wabash River crossing predicted from the seven prediction distribution techniques with a screen line count of traffic over the four bridges. To achieve this, a counting program was established that produced directional counts on the Main Street Bridge, the Brown Street Bridge, and the William Henry Harrison Bridge. Traffic volumes on the U.S. 52 bypass bridges were obtained from a study being conducted



VOLUME EXPANSION FACTORS FOR URBAN AREAS IN INDIANA REF. (9)
FIGURE 8

on the bypass.

The counting commenced on Monday, March 8, 1965 and continued until Friday March 26, 1965. The month of March was chosen for the period because of a study of automatic traffic recording stations indicated that at this time of year the traffic was at its yearly average (figure 8). This means that the expansion factor for volume adjustment was one, and it was not necessary to adjust the count for seasonal variation.

Two fifteen minute recording counters were installed at each of the three bridges, one in each direction of movement. Total volumes across the bridge, counted as two axle vehicles were registered. To convert the counts to passenger cars, light trucks, and three, four and five axle trucks, short classification counts were conducted. Three half hours counts were made at each bridge for each direction of traffic flow. One count was made during a peak hour period, the other two were made at a daylight off peak hour and an evening off peak hour respectively. The day was divided into two peak hour periods, morning and evening, and two off-peak hour periods, afternoon and late evening to early morning. The distribution of vehicles by type was determined by applying the suitable classification factor.

The total volume of passenger cars crossing the screen line was obtained by summing all factored bridge crossing volumes for an average day. From previous work

it was decided to include only counts from Tuesday, Wednesday and Thursday. It was felt that the weekend traffic was not typical of movement in the area and that the traffic on Friday and Monday exhibited some instability due to the student population.

The resulting average daily volume of passenger cars was used to evaluate the trip distributions.

Procedure for analysis of trip distribution

A screen line count across the Wabash River was used to determine the acceptability of the distribution techniques. It was at first thought that a statistical test could be used to evaluate the accuracy of the prediction method. However, after consultation with the statistical consultant, this idea was discarded because only one value existed for the comparison and no statistical test could be performed. As a criterion for accepting or rejecting a method, it was decided that the range of acceptability would be plus or minus ten percent of the screen line count.

Once a method had been termed acceptable, it was desired to know if this method was any different than any other acceptable method. This lent itself to statistical testing. The test chosen for this was a pair wise T-test comparison of trip interchanges to check for zero variance. If no variance was found, the method was considered statistically the same.

It was decided to include only [illegible] day and Thursday [illegible] not typical [illegible] Friday [illegible] dent [illegible]

[illegible]

[illegible]

[illegible] would [illegible]

[illegible] question is [illegible] other factors [illegible] testing. [illegible] comparison of [illegible] If no variance was found [illegible] tically the same.

RESULTS

Determination of O-D zones

The growth which had taken place in the area coupled with the changes in land use in certain parts of both cities necessitated addition and modification of the origin and destination zones.

Three zones required subdivision, two in West Lafayette and one in Lafayette. Zone three was broken up into two new zones, zone three which is termed commercial and zone 103 which is residential. Original zone four was portioned into zone 102 which is commercial, zone 4, 104 and 106 which are residential and zone 105, Happy Hollow Park. In Lafayette, zone 58 was divided into new 58, and 96 which are residential and zone 97, Market Square Shopping, commercial. All trips to the original zones 3, 4, and 58 were proportioned among the new zones respectively.

It was found convenient to combine part of the original zone 79 with zone 67. Trips from 79 were added to those from zone 67 to produce total trips from the new 67. Zone 79 was then considered to be a new zone for the updating procedure.

A major change in the allocation of land for stu-

TABLE 8

STATUS OF ORIGIN DESTINATION ZONES

ZONE	STATUS
1	unchanged
2	unchanged
3	partitioned from original zone 3
4	partitioned from original zone 4
5	unchanged
6	unchanged
7	unchanged
8	unchanged
9	unchanged
10	modified - trip table intact
11	unchanged
12	unchanged
13	unchanged
14	unchanged
15	unchanged
16	unchanged
17	unchanged
18	unchanged
19	unchanged
20	unchanged

TABLE 8 (cont.)

STATUS OF ORIGIN DESTINATION ZONES

ZONE	STATUS
21	modified - trip table intact
22	unchanged
23	unchanged
24	unchanged
25	new
26	new
27	new
28	new
29	new
30	unchanged
31	unchanged
32	unchanged
33	unchanged
34	unchanged
35	unchanged
36	unchanged
37	unchanged
38	unchanged
39	unchanged
40	unchanged
41	unchanged

TABLE 8 (cont.)

STATUS OF ORIGIN DESTINATION ZONES

ZONE	STATUS
42	unchanged
43	unchanged
44	unchanged
45	unchanged
46	unchanged
47	unchanged
48	unchanged
49	enlarged
50	unchanged
51	unchanged
52	unchanged
53	unchanged
54	unchanged
55	unchanged
56	enlarged
57	unchanged
58	partitioned from original zone 58
59	unchanged
60	unchanged
61	unchanged
62	unchanged

TABLE 8 (cont.)

STATUS OF ORIGIN DESTINATION ZONES

ZONE	STATUS
63	unchanged
64	unchanged
65	unchanged
66	unchanged
67	combination of original zone 67 and 79
68	unchanged
69	unchanged
70	unchanged
71	unchanged
72	unchanged
73	unchanged
74	unchanged
75	partitioned from original zone 75
76	unchanged
77	unchanged
78	unchanged
79	new
80	enlarged
81	new
82	partly new and partly partitioned from original 75

TABLE 8 (cont.)

STATUS OF ORIGIN DESTINATION ZONES

ZONE	STATUS
83	new
84	new
85	partly new and partly partitioned from original 75
86	new
87	new
88	new
89	new
90	new
91	new
92	new
93	new
94	new
95	new
96	partitioned from original zone 58
97	partitioned from original zone 58
98	new
99	new
100	new

TABLE 8 (cont.)

STATUS OF ORIGIN DESTINATION ZONES

ZONE	STATUS
101	new
102	new
103	new
104	new
105	partitioned from original zone 4
106	partitioned from original zone 4

dent residences at Purdue University required a modification of zones 21 and 10. To account for this shift. Zone 75 was made somewhat smaller to transfer a part of a subdivision to a zone which contained the remainder of the subdivision. The excess of zone 75 was placed in zones 82 and 85. Two zones were increased in size to account for new growth. These were zone 49 which was enlarged to include the Lafayette Grain Company and zone 56 to include a light industrial plant. The status of all zones for 1964 is given in table 8.

Division of zones by predominant land use

As discussed in the procedure, a zone was assigned a land use for the evaluation study based on the predominantly land use. The final assignment was 68 residential zones, 15 commercial zones, 18 industrial zones, 3 institutional zones and 2 recreational zones. Tables 9, 10, 11, 12 and 13 show the allocation of land use.

Growth factors

Calculation of growth factorsby method 1, interactance, produced growth factors that ranged from 0.241 to 62,110,000. Generally, the effect of method one technique produced very low growth factor when the growth factors for the individual variables was less than one. When the individual variable growth factorswere all greater than five,

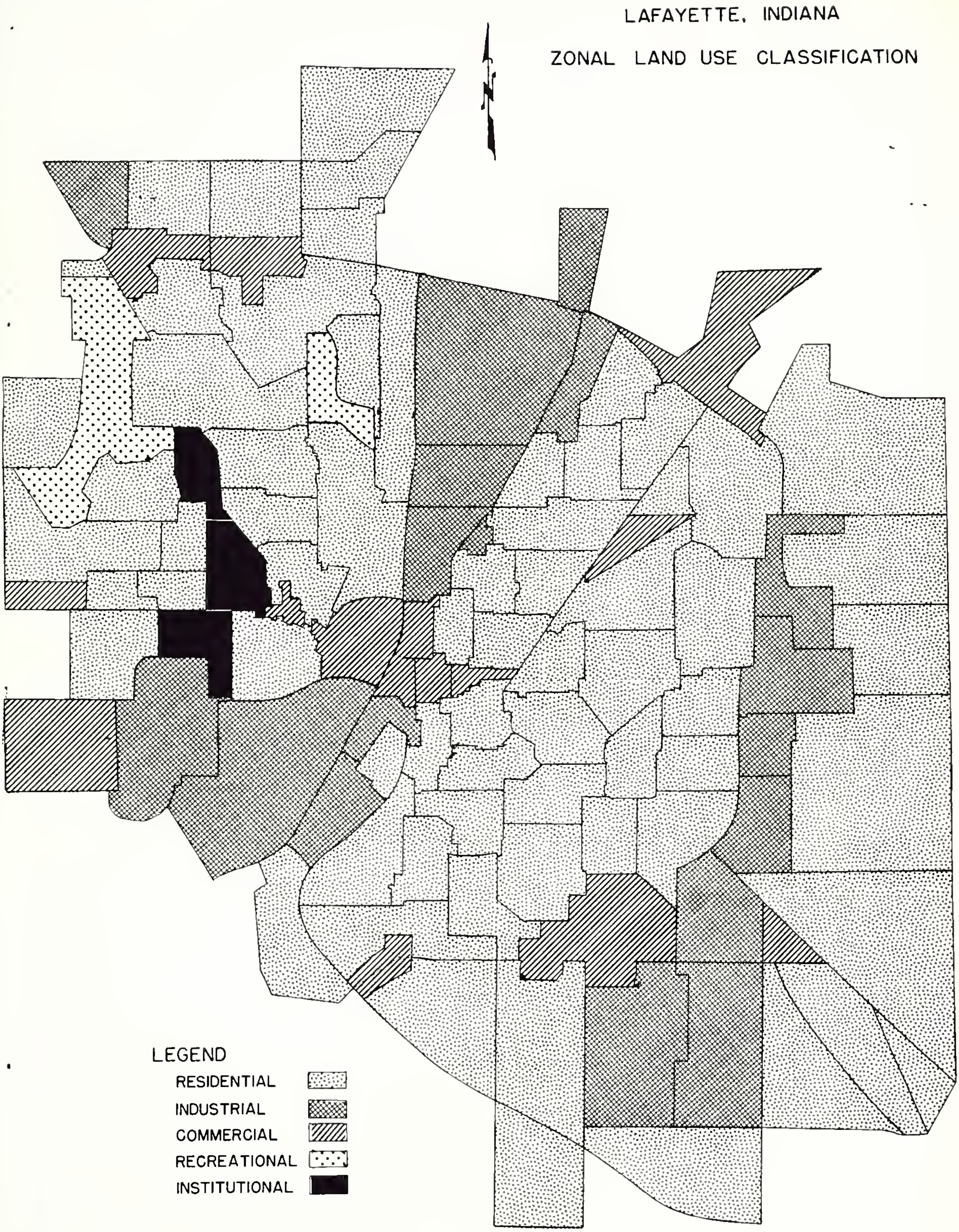

LAFAYETTE, INDIANA
ZONAL LAND USE CLASSIFICATION
LEGEND
RESIDENTIAL
INDUSTRIAL
COMMERCIAL
RECREATIONAL
INSTITUTIONAL

FIGURE 8A

TABLE 9

RESIDENTIAL ZONES CLASSIFICATION

ZONE	ZONE	ZONE	ZONE	ZONE	ZONE	ZONE	ZONE	ZONE
1	12	29	45	59	70	82	91	100
4	14	31	46	60	71	83	92	103
5	15	33	51	61	72	84	93	104
6	16	34	52	62	73	85	94	106
8	19	39	53	63	74	86	95	
9	21	40	55	66	75	87	96	
10	27	41	57	68	76	89	98	
11	28	42	58	69	81	90	99	

TABLE 10

COMMERCIAL ZONE CLASSIFICATION

ZONE	ZONE	ZONE	ZONE
3	25	37	79
17	26	38	97
18	35	54	102
22	36	77	

TABLE 11

INDUSTRIAL ZONE CLASSIFICATION

ZONE	ZONE	ZONE	ZONE	ZONE	ZONE	ZONE
23	32	47	50	65	80	
24	43	48	56	67	88	
30	44	49	64	78	101	

TABLE 12

INSTITUTIONAL ZONE CLASSIFICATION

ZONE	ZONE	ZONE
7	13	20

TABLE 13

RECREATIONAL ZONE CLASSIFICATION

ZONE	ZONE
2	105

the resultant growth factor became very large. The way in which the values of the growth factor varied showed the sensitivity of the multiplier effect on expanding or contracting zone growth factors.

The arithmetic growth factor technique, method two, produced growth factors that ranged from 0.714 to 432. Since an average of all variable factors was used, an extremely large or extremely small individual variable factor did not expand or reduce the resultant growth factor to any considerable degree. Generally, when the individual factors were less than one or near one in value, factors calculated by method 1 were smaller than comparable factors calculated by method 2. The opposite was true when the individual factors were somewhat greater than one. Comparable values for growth factors by method one had greater values than those calculated by method two.

In the computation of growth factors by method three, three regression equations were developed for the prediction of zonal trips.

The model developed for residential zones was:

$$y = 8.621 + 2.091 X_2 + 0.010 X_2 X_3^2$$

where y = trip ends per acre

X_2 = automobiles per acre

X_3 = population per acre

The coefficient of determination, multiple R^2 for

the equation was 0.8204, while the standard error of the estimate was 9.6929.

The model developed for commercial zones was:

$y = 26.509 + 34.600X_3$

where y = trip ends per acre

X_3 = number of establishments per acre.

The coefficient of determination, multiple R^2, was 0.9474 with a standard error of estimate of 54.0080.

The final model developed, for industrial zones was:

$y = 6.022 + 7.613\ X_2X_3$

where y = trip ends per acre

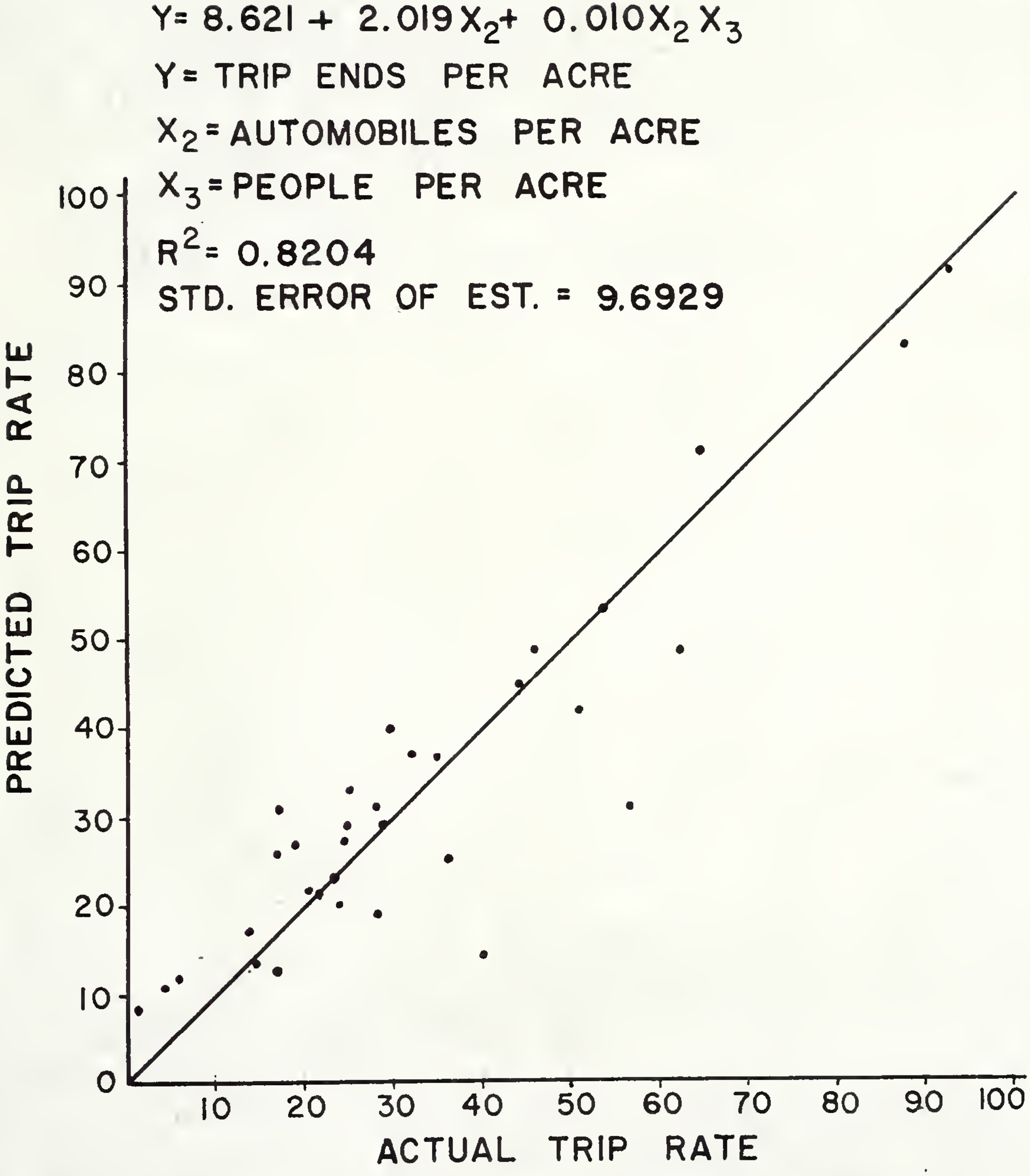
X_2 = employees per acre

X_3 = establishment per acres

The coefficient of determination, multiple R^2, was 0.9561 and the standard error of estimate was 5.3042.

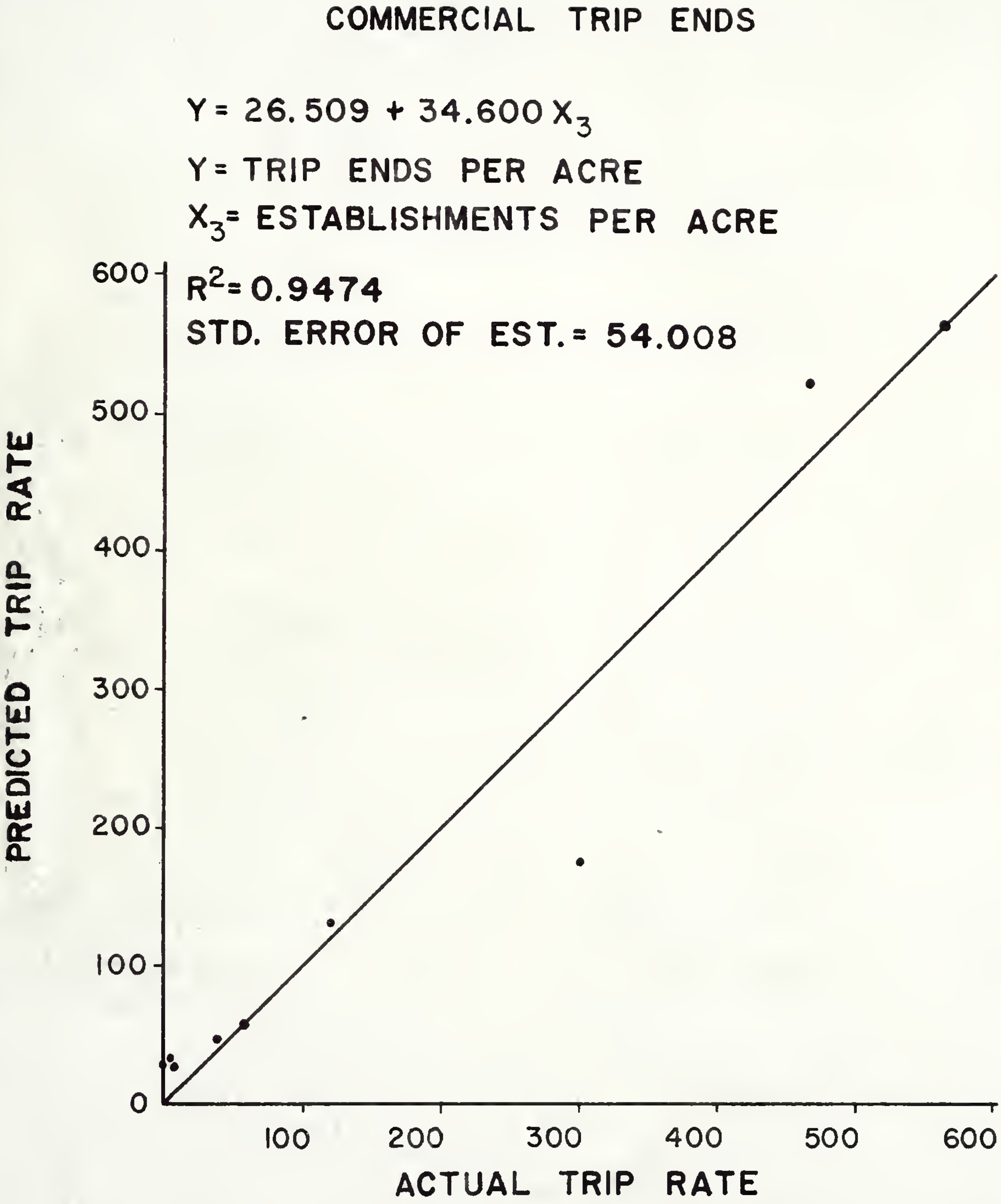
Growth factors determined by methods three ranged from 0.336 to a value of 3.411. The reason for the comparatively small value of the largest growth factor was that the regression model always predicted a significant number of trips in the new zones for 1952 even though the value of the input variables was relatively small. This is a characteristic of regression models and is due to the constant in the equation. The effect of a large increase in growth was minimized using this method, with the greatest

RESIDENTIAL TRIP ENDS



REGRESSION ANALYSIS OF RESIDENTIAL ZONES

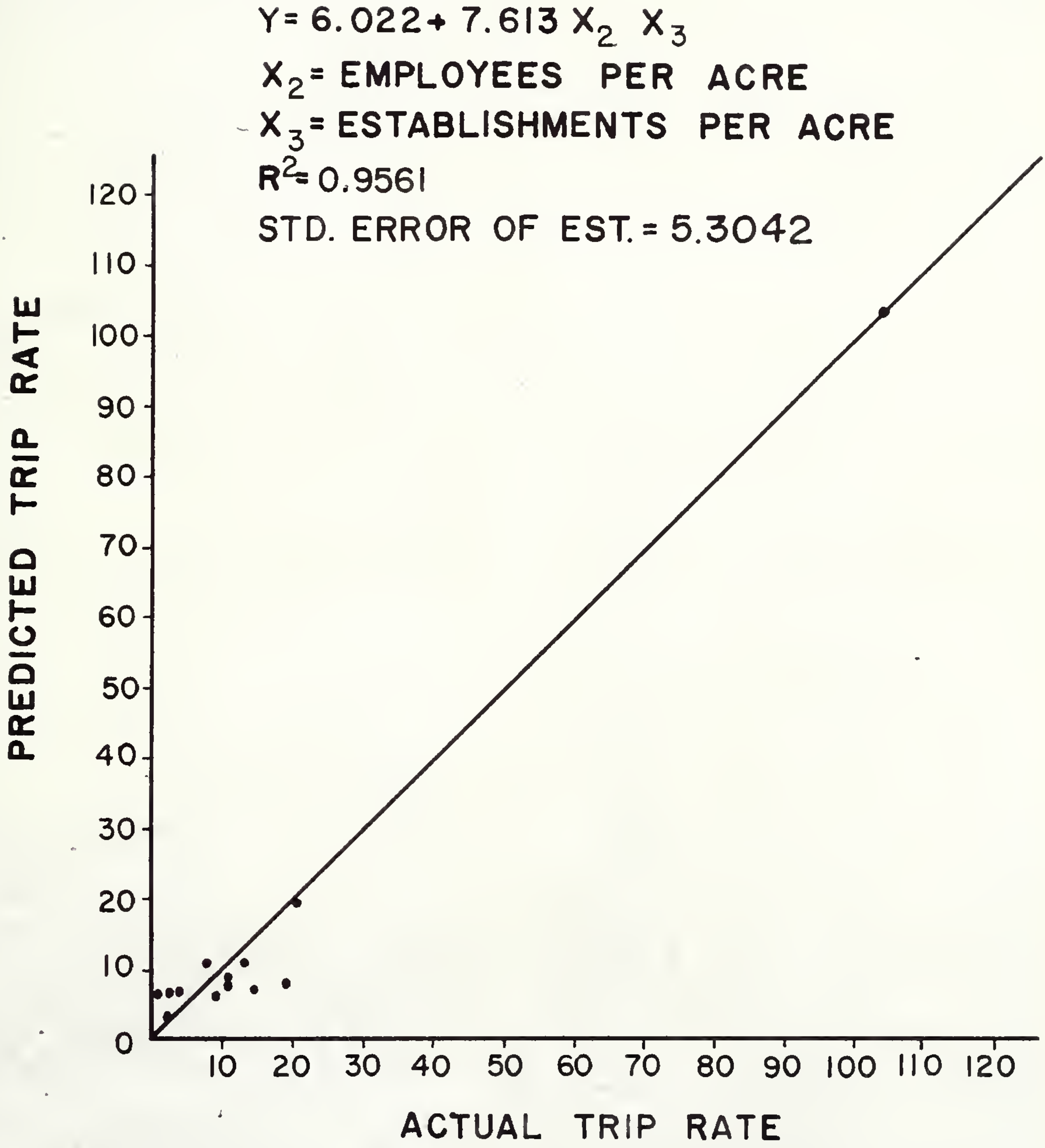
FIGURE 9



REGRESSION ANALYSIS OF COMMERCIAL ZONES

FIGURE 10

INDUSTRIAL TRIP ENDS



$Y = 6.022 + 7.613 X_2 X_3$

X_2 = EMPLOYEES PER ACRE

X_3 = ESTABLISHMENTS PER ACRE

$R^2 = 0.9561$

STD. ERROR OF EST. = 5.3042

REGRESSION ANALYSIS OF INDUSTRIAL ZONES

FIGURE 11

TABLE 14

Final Growth Factor for Distribution

ZONE	G.F.1	G.F.2	G.F.3
1	7.500	2.167	1.002
2	2.000	2.000	2.000
3	36.302	6.285	1.213
4	16.724	2.807	1.123
5	4.765	1.779	1.156
6	2.128	1.321	1.219
7	1.976	1.976	1.976
8	1.530	1.162	1.012
9	268.489	7.957	1.039
10	0.860	1.106	0.336
11	0.568	0.863	0.860
12	1.052	1.337	2.668
13	1.976	1.976	1.976
14	0.627	0.874	0.677
15	1.469	1.166	1.003
16	0.839	0.952	1.028
17	2.190	1.724	0.932
18	1.012	1.008	0.963
19	1.087	1.049	0.913
20	1.976	1.976	1.976
21	7.906	2.000	2.959
22	3.000	1.750	1.008
23	0.909	0.955	1.000
24	13.000	3.625	1.004
25	650.000	37.500	1.441
26	325.000	35.000	1.203
27	939,700.000	330.000	1.087
28	2,120.890	16.078	1.140
29	28,440.000	92.000	1.282
30	0.508	0.714	0.787
31	0.471	0.826	0.611
32	0.719	0.850	0.887
33	0.437	0.759	0.643
34	0.670	0.888	0.814
35	0.602	0.777	0.832
36	0.668	0.818	0.835
37	0.480	0.704	0.866
38	1.194	1.112	0.951

TABLE 14 (cont.)

ZONE	G.F.1	G.F.2	G.F.3
39	0.422	0.763	0.635
40	0.505	0.799	0.549
41	0.686	0.882	0.802
42	0.825	0.939	0.944
43	2.082	1.503	1.228
44	1.104	1.052	1.098
45	0.889	0.965	0.972
46	0.996	1.017	1.078
47	2.209	1.519	1.059
48	9.054	3.009	1.045
49	1.746	1.437	1.089
50	0.783	0.911	0.954
51	0.958	0.986	1.001
52	0.726	0.905	0.918
53	1.752	1.216	1.419
54	1.556	1.256	1.006
55	6.627	2.241	1.371
56	0.416	0.969	0.710
57	22.756	3.369	1.192
58	1.209	1.065	1.036
59	0.751	0.879	0.967
60	0.931	1.004	1.304
61	0.886	0.961	0.965
62	0.990	1.008	1.074
63	0.883	0.962	0.981
64	5.136	2.278	2.360
65	7.808	2.295	3.308
66	1.203	1.065	1.138
67	2.264	1.543	1.875
68	1.212	1.070	1.080
69	1.063	1.034	1.168
70	1.001	1.003	1.072
71	1.298	1.092	1.110
72	0.796	0.932	0.967
73	0.834	0.949	1.020
74	1.185	1.063	1.117
75	0.241	0.768	1.009
76	1.593	1.176	1.268
77	543.600	23.325	1.139
78	0.707	0.854	0.959
79	168.000	84.500	1.000
80	6.834	2.639	1.099
81	2.511	1.518	1.031
82	15.722	2.762	1.051
83	49,589.000	53.821	1.134

TABLE 14 (cont.)

ZONE	G.F.1	G.F.2	G.F.3
84	4,421.900	26.115	3.411
85	236,769.000	69.667	1.125
86	13,070,000.000	243.798	2.191
87	11,460.000	25.963	1.047
88	4,725.000	165.000	1.091
89	19,440.000	2.981	1.007
90	0.933	0.978	1.000
91	57.152	6.111	1.022
92	4.125	1.792	1.004
93	34.650	3.317	1.022
94	51.976	4.717	1.043
95	13,750.000	43.077	1.060
96	52,110.000	89.020	2.852
97	6,945.500	134.250	1.652
98	36.000	5.333	1.017
99	13,003.000	30.733	1.114
100	783.888	14.252	1.067
101	6,795.000	382.000	2.027
102	808.000	54.500	1.117
103	3,681.990	24.562	1.246
104	62,110,000.000	432.000	1.408
105	2.000	2.000	2.000
106	32,770.000	92.324	1.209

damping effect being in the new zones. The list of growth factor computed by each method is listed in table 14.

Trip generation for the Gravity Model

The regression equations were used to predict the 1964 trip ends to be distributed by the Gravity Model. In many instances, it appeared that these equations overpredicted the zonal trip ends. A reason for this could have been because the trip ends per acre were computed on total acreage in a zone. If effective acreage in each zone would have been used, it is quite possible that the trip ends predicted would be more reasonable. Table 15 is a listing of 1952 and 1964 trip ends determined by the regression equations.

Screen line crossings

Volumes were recorded at the three bridges near the CBD, Since the monthly adjustment factor for the month of March, during which the counting program was conducted was unity, no expansion of the volume count was necessary. Classification counts done at all three city bridges to convert the axle counts to vehicles indicated that three or more axles vehicles constituted at the most 3 percent of the volume. This was on the Harrison bridge. Main street bridge had 2½ percent of three or more axle vehicles while the Brown street had virtually no vehicles of this type.

TABLE 15

Predicted Trips by Regression Analysis

ZONE	1952	1964
1	1130.89	1133.54
2	-	-
3	2273.89	2759.27
4	1076.00	1208.48
5	3336.91	3858.22
6	1956.62	2384.36
7	-	-
8	1279.85	1295.79
9	1849.66	1922.13
10	1874.01	629.15
11	3126.43	2689.93
12	1495.67	3991.09
13	-	-
14	3772.48	2554.75
15	2897.85	2906.10
16	3329.60	3421.60
17	4024.07	3743.44
18	2767.27	2663.84
19	4174.37	3809.76
20	-	-
21	2309.38	6832.50
22	4491.57	4526.51
23	1354.43	1354.28
24	1551.13	1556.67
25	705.79	1016.98
26	679.25	817.27
27	636.93	692.13
28	885.55	1009.19
29	887.03	1137.43
30	812.12	638.95
31	1260.65	770.14
32	331.31	293.74
33	2410.83	1549.12
34	3144.38	2559.95
35	7407.61	6161.85
36	14502.02	12113.84
37	2319.93	2008.76
38	1426.71	1357.21
39	4541.47	2885.81
40	5389.24	2956.59
41	3978.92	3192.59

TABLE 15 (cont.)

ZONE	1952	1964
42	3159.25	2981.51
43	613.16	759.12
44	1319.67	1448.76
45	3303.08	3211.73
46	2586.84	2787.65
47	636.06	673.53
48	2363.10	2469.53
49	512.96	558.68
50	588.20	561.09
51	2268.40	2270.20
52	2301.10	2112.55
53	2711.01	3846.58
54	5445.45	5478.97
55	3407.91	4670.68
56	1392.30	988.74
57	1851.21	2206.02
58	2072.81	2147.05
59	2698.39	2609.34
60	2577.02	3361.58
61	2708.81	2613.66
62	1088.38	1169.23
63	2773.93	2720.40
64	1247.56	2944.85
65	536.74	1775.62
66	2528.15	2877.08
67	2169.68	4067.55
68	3609.05	3898.13
69	1792.36	2094.36
70	3404.99	3651.61
71	1453.49	1613.42
72	1670.43	1615.26
73	1844.28	1881.90
74	1511.19	1687.66
75	1091.07	1101.26
76	3050.30	3868.89
77	5760.95	6561.34
78	1021.54	979.29
79	986.97	986.97
80	1183.04	1300.49
81	1114.55	1149.38
82	1583.58	1664.98
83	1837.79	2084.62
84	3081.00	10510.20
85	1441.75	1622.40
86	2326.98	5099.24

TABLE 15 (cont.)

ZONE	1952	1964
87	1981.25	2074.29
88	1471.38	1605.40
89	1524.04	1534.03
90	569.81	569.81
91	3631.60	3712.34
92	4144.98	4161.45
93	1483.57	1516.02
94	2185.63	2278.54
95	3549.66	3762.70
96	393.14	1121.08
97	1484.76	2452.31
98	119.40	121.42
99	1138.85	1268.26
100	963.04	1027.72
101	548.56	1111.83
102	2067.23	2308.66
103	986.80	1229.74
104	1934.98	2724.07
105	-	-
106	731.82	884.50

For this reason, it was decided not to adjust the field counts of these vehicles.

Adjustment of the counts was made to determine passenger cars. Values of 93.9 percent and 76.0 percent of total traffic was found to be passenger cars on the Main Street bridge for peak and off-peak periods respectively. The percentage of passenger cars on the Brown street bridge was 95.2 for peak hour and 89.6 for off-peak hour period. On the Harrison bridge, the peak hour percentage was 92.9 and for off-peak, 80.7. In all cases, the peak hour volume comprised six hours of the day. The weighted percentage of passenger car volume was 91.8, 83.4, and 86.2 for the Brown Street, Main Street and Harrison bridges respectively.

From information obtained from the U.S. 52 By-pass study, it was estimated that 29.68 percent of the traffic volume was due to local passenger cars. This factor was applied to the annual average daily traffic (AADT) for the segment of the by-pass which included the bridges.

The 1965 AADT for the four bridges were:

Brown Street	6,012	vehicles
Main Street	18,774	"
William Henry Harrison	16,984	"
U. S. 52 By-pass	13,047	"

The average annual daily local passenger car volumes at the bridges were:

Brown Street	5,519
Main Street	15,657
William Henry Harrison	14,640
U. S. 52 By-pass	3,872

The total river crossing was 39,688 passenger cars per day.

Acceptance criteria was established as the range given by plus and minus term present of the volume. The resulting acceptance range was 35,719 to 43,657 local passenger cars per day.

Growth factor trip distribution

Growth factors which had been computed by each of the three methods were inputed into both the Detroit and Fratar equations for the trip distributions. Since a range in magnitude existed between the growth factorsproduced by each of the methods, it was anticipated that the distributions for same growth factor method would be different, while total tripswould remain the same. Using the 1952 total trip ends as a common reference, a comparison can be made of the methods by dividing by the 1952 trip ends to obtain a prediction ratio.

TABLE 16

TRIP ENDS PREDICTED IN LAFAYETTE BY DISTRIBUTION TECHNIQUES

METHOD	NUMBER OF TRIP ENDS	PREDICTION RATES
1952 Survey	178,624	
Detroit G.F.1	1,132,132.05	6.338
Detroit G.F.2	327,267.32	1.832
Detroit G.F.3	257,012.47	1.439
Fratar G.F.1	1,132,198.08	6.338
Fratar G.F.2	327,226.00	1.832
Fratar G.F.3	256,990.28	1.439
Gravity Model	283,096.09	1.585

The analysis of the area trip factors as shown in Table 16 bore out the hypothesis that the resulting trip ends after distribution by the different techniques were the same for the respective growth factor methods. However, each growth factor method predicted a different range of growth in the study area. A ten year growth of over 6.3 was predicted by the interactance or growth factor method one. For a ten year period, this was considered too high a growth and considerable concern arose as to the use of interactance for growth factor computation. Methods two and three, aritmetic average and regression, produced total area growth factors of 1.832 and 1.439 respectively. Both of these values were considered as being a realistic measure of a ten year area wide growth. This gives annual growth rates of about 5 percent and about 3 percent respectively which are considered reasonable.

A first impression of distribution by both the Fratar and Detroit Models would seem to indicate that the predicted zonal interchange would be identical. Such was not the case. Even though both models have a similar appearance, the normalizing factors within the model sufficiently alters each so that the final distribution are not the same. In some instances trips predicted by each distribution technique for a single growth factor method were similar, but generally, all that could be said was that the interchanges were of the same magnitude (see Table D-7). When the three sets of trips for the Fratar distribution technique were

compared with the three sets by the Detroit technique, a certain relationship existed with both sets in many cases. The differences in magnitude for the sets computed by the Fratar method were comparable to the differences in magnitude resulting from the Detroit Method. It must be remembered that this is only a general overview and that this relationship did not hold rigidly in every case.

Further analysis of the distribution techniques and growth factor methods appears to indicate that the final distribution is extremely sensitive to the range in magnitude of the growth factors determined by a particular method. From observation of the interchanges, there is an indication that most trips are forced between zones which have growth factors of the same magnitude while interchange between zones with growth of different magnitude are kept small. In other words, an interchange between two zones of large magnitude growth or two zones of small magnitude growth is more likely than interchange between a zone of large magnitude, and a zone of small magnitude. This becomes more pronounced as the range in magnitude increases.

The magnitude problem also raises another question in analyzing this distribution. Growth factor method one produced several very large zonal growth factors. The computer programs would not run until an upper limit of one thousand was placed on the factors. No plausible explanations can be given for this although this could be attribut-

ed to some idosyncrasy of the computer.

Limitation of the mechanical computations and the forcing of trips between specific zones raises the question, what should an upper limit on growth factors be? Provided that short term forecasting is desired (between ten and twenty five years), the researcher is of the opinion that an upper limit of one hundred be placed on the factors, and this should only occur in isolated instances. For anything under ten years and upper limit of fifty should be used but probably a factor of ten is more realistic. Estimation for over twenty five years is at the most done with tongue in cheek and again an upper limit of one hundred should be used. Just as critical as the magnitude is the range in magnitude. It is the opinion of the researcher that in no case should there be more the one level of magnitude difference between the smallest and largest growth factors.

An analysis of the efficiency of the Detroit and Fratar techniques from a time standpoint was not possible because there was no major attempt to make each computer program efficient as possible. The only comparison possible was between the number of iterations required for the solution: this is indicated in table 17.

TABLE 17

NUMBER OF ITERATIONS REQUIRED BY GROWTH FACTOR METHODS

METHOD	NUMBER OF ITERATIONS
DETROIT G.F.1	9
DETROIT G.F.2	11
DETROIT G.F.3	14
FRATAR G.F.1	9
FRATAR G.F.2	4
FRATAR G.F.3	4

The Fratar technique appeared to require just as many or fewer iterations than the Detroit technique. An interesting trend seems apparent. When the magnitude of the growth factors increase, the number of iterations for the Fratar decreases while the reverse is true for the Detroit Method.

A certain irrationality became apparent in analyzing the trip interchange. In several instances high volumes of trips were predicted between zones which would not normally produce that magnitude of trips. This was especially true of interchange between two commercial zones or two industrial zones. This drawback could possibly be alleviated by performing a distribution for each trip purpose.

Gravity Model

The trip ends for the gravity model had been determined by regression analysis. The 1953 factor for the gravity model was 1.585 (table 16). This was considered a reasonable increase in growth.

Calibration of the model for each of four purposes, work, commercial, home based other, and non-home based other, was performed according to the Bureau of Public Roads procedure. Friction factors were determined using the trial error technique as outlined. No more than three iterations were required before a satisfactory trip frequency curve was obtained for each of the four trip purposes, see figures 12, 13, 14 and 15. The final travel time friction factors for each purpose were determined from a hand fitted line. It was desired to obtain the least complicated curve as possible and the factors for each travel time were forced to conform to this requirement within the limitation of the calibration procedure.

The curve of travel times versus friction factors for work trips (figure 16) appears as a straight line on a semi-log plot. A log-log plot of commercial trips yielded a straight line curve (Figure 17). Home based other trips produced a straight line curve when plotted on semi-log paper (figure 18). A slight curvature at small travel times

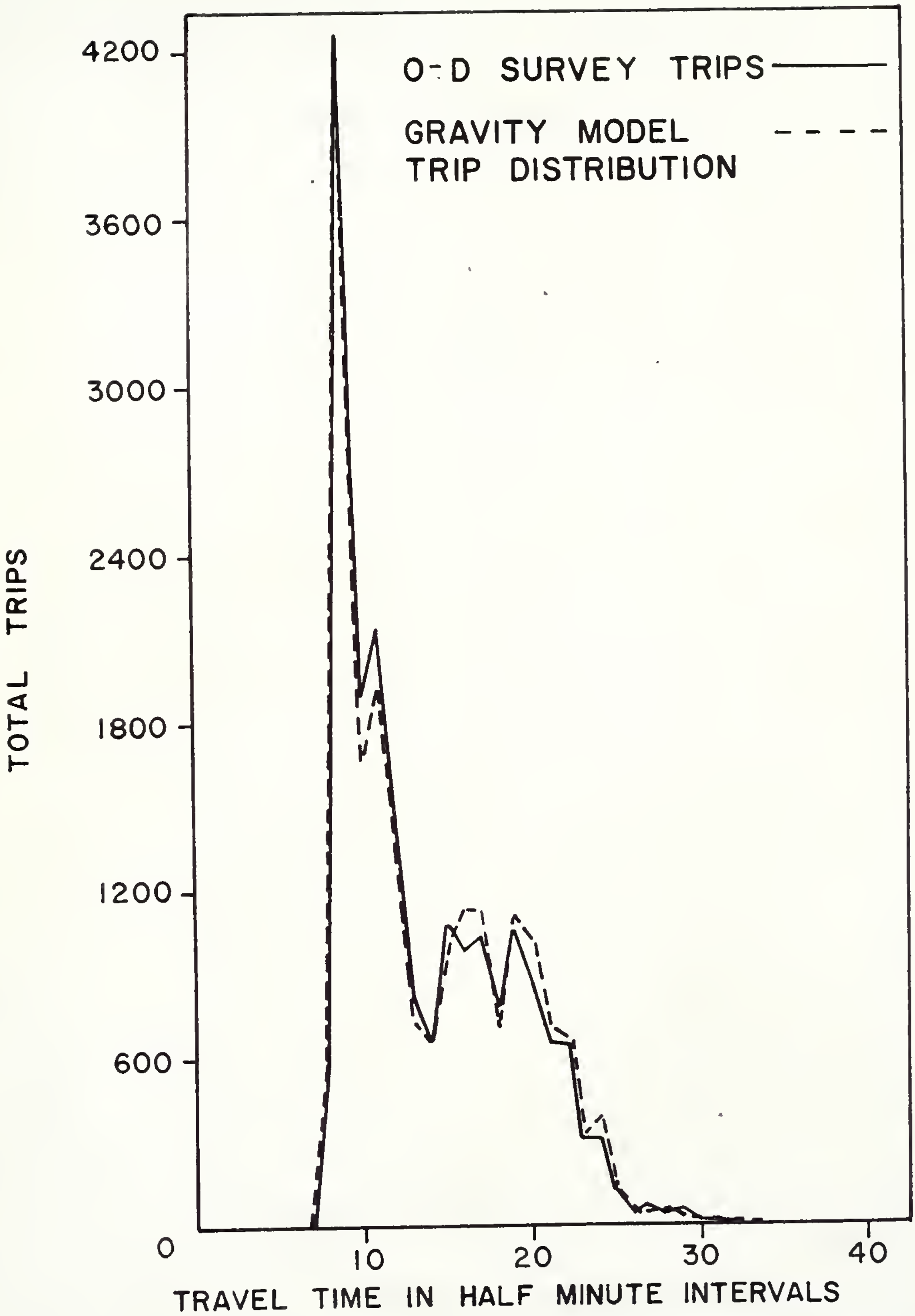
was obtained using a semi-log plot for non-home based trips (figure 19).

Travel time factors for work trips range from 14.1 at 3.5 minutes total time to 0.084 at 25 minutes total time. Commercial trip factors had a range of 32.5 at 3.5 minutes to 0.34 at 25 minutes. The range for home based trips was 16.2 at 3.5 minutes to 0.072 at 25 minutes, while non-home based trips ranged from 12.1 to 0.37 for the respective times. An analysis shows that commercial trips are most sensitive to the friction factor while home-based, work, and non-home based other are less sensitive in that order.

Further calibration yielded the "K" adjustment factors. Most of these values were less than ten with many very close to 1.0. However, there were several isolated cases where the value was above one thousand. An explanation for this could be due to the structure of the calibrations equation (see calibration procedure).

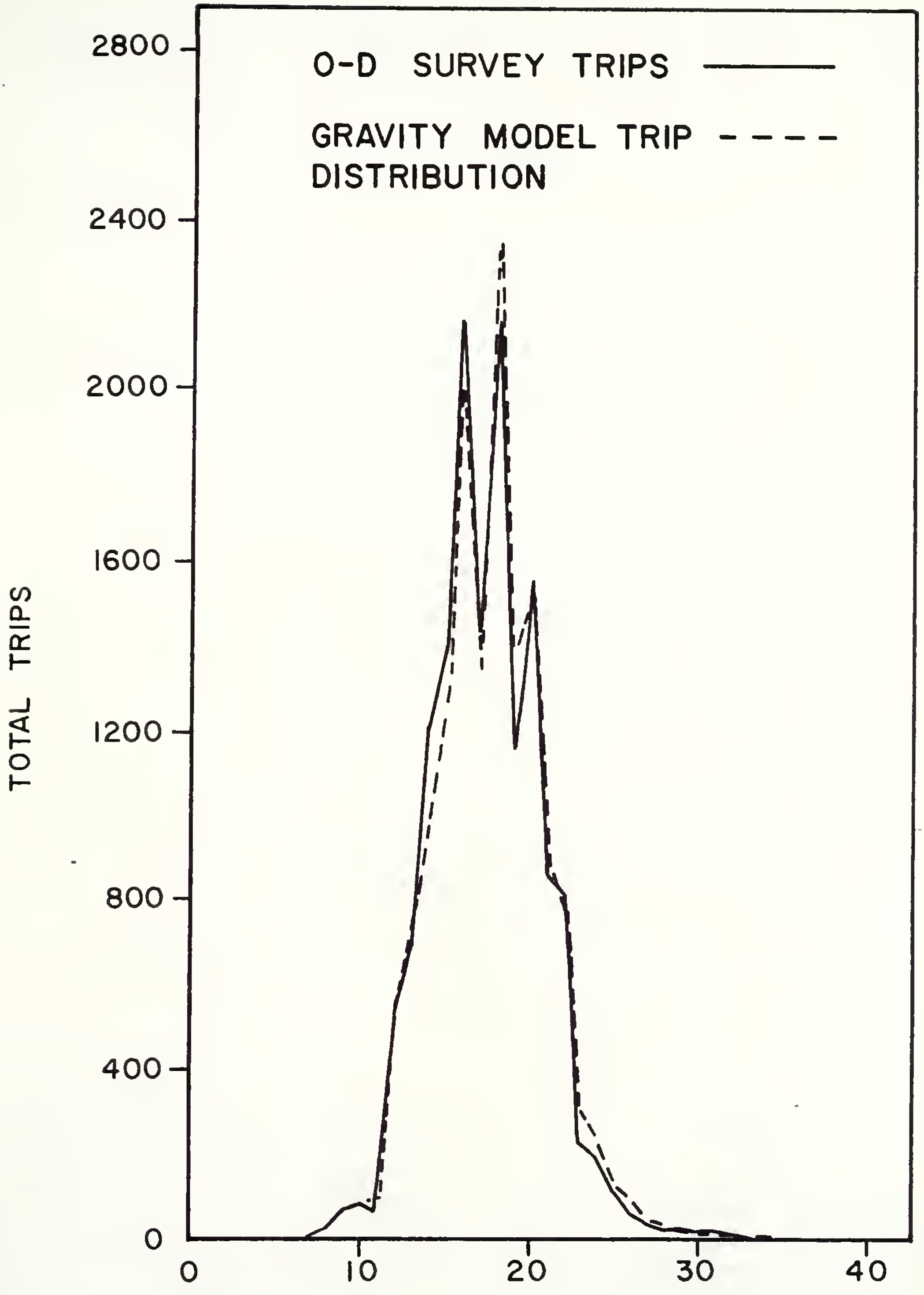
$$K_{ij} = \left(\frac{T_{ij}}{T_{ij}'}\right) \left(\frac{1 - \frac{T_{ij}'}{Ti}}{1 - \frac{T_{ij}}{Ti}}\right)$$

If T_{ij}' had been very small after the F calibration, it is possible for K_{ij} to become very large. Another interesting case produced a negative "K" factor. This could be attributed to a very large T_{ij}' resulting from the F cal-



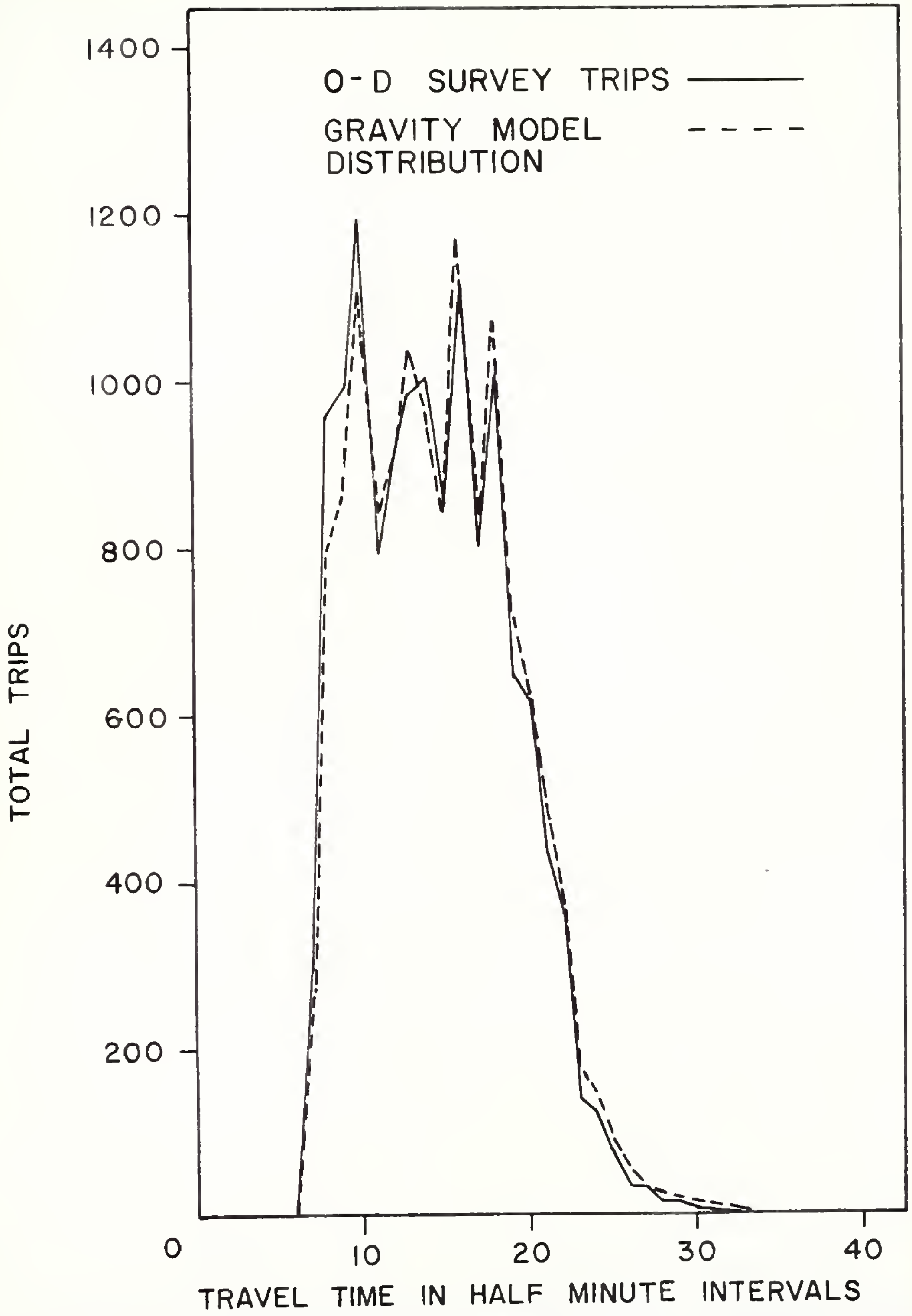
F FACTOR CALIBRATION - WORK TRIPS

FIGURE 12



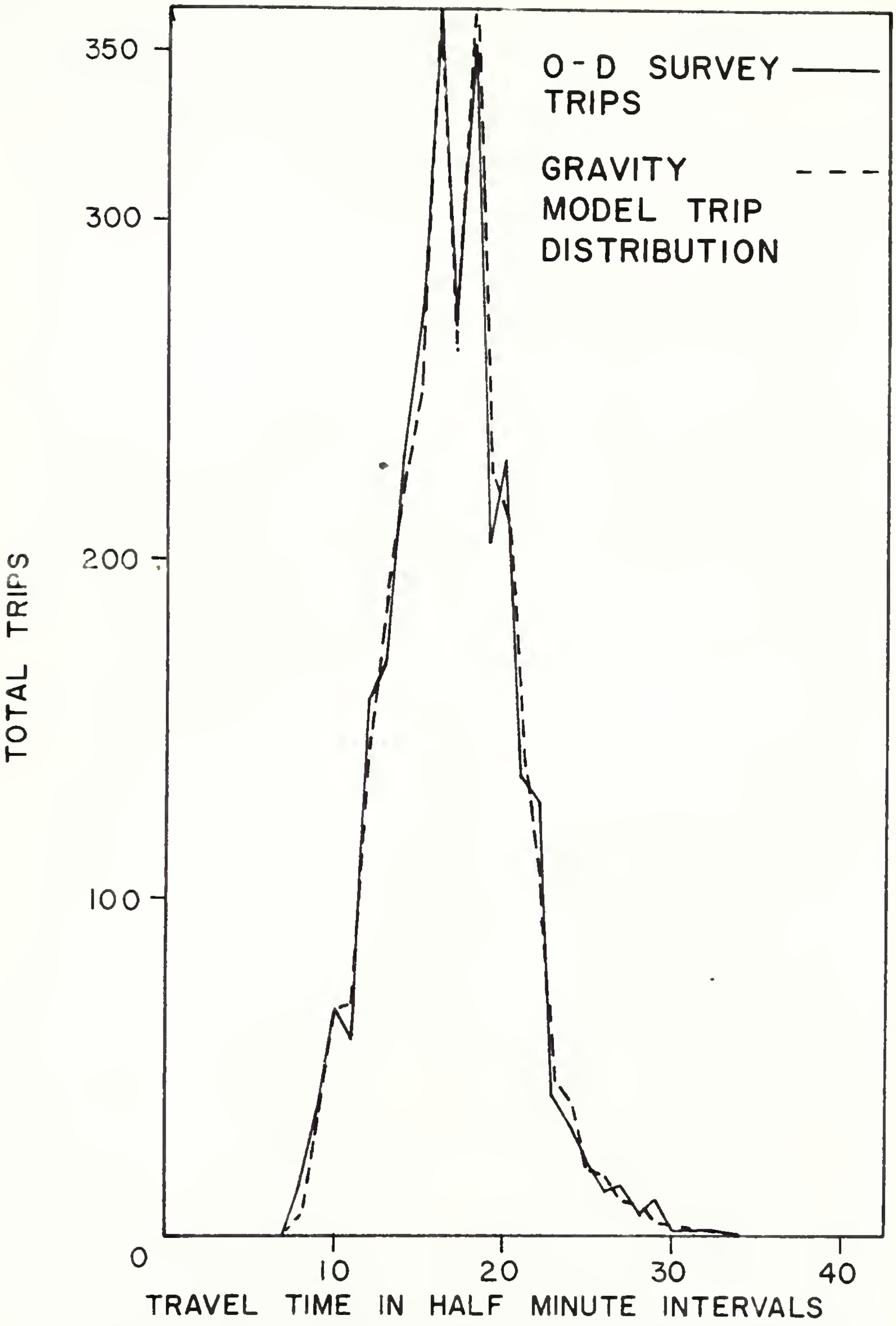
F FACTOR CALIBRATION - COMMERCIAL TRIPS

FIGURE 13



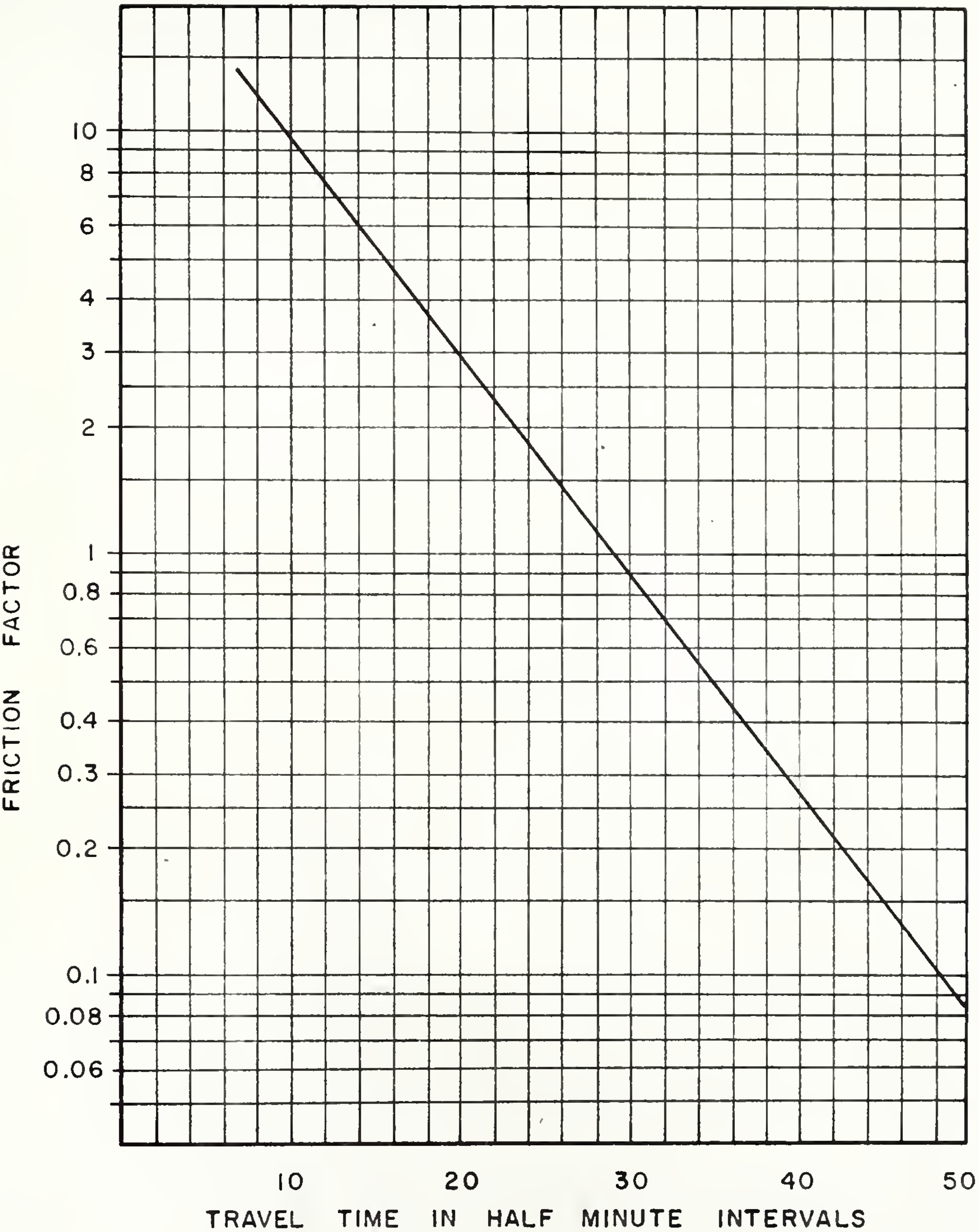
F FACTOR CALIBRATION-HOME BASED OTHER TRIPS

FIGURE 14



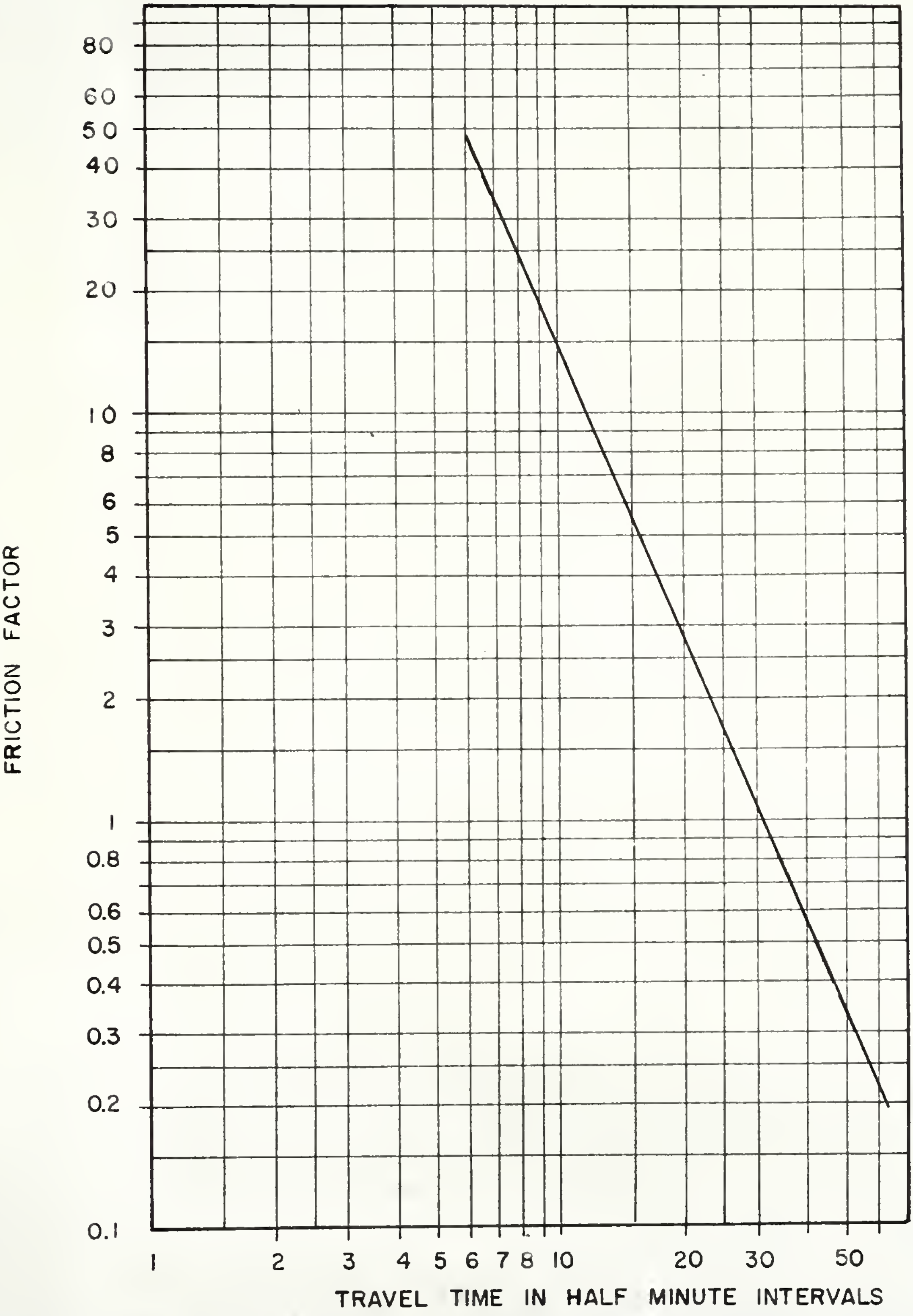
F FACTOR CALIBRATION- NON HOME TRIPS

FIGURE 15

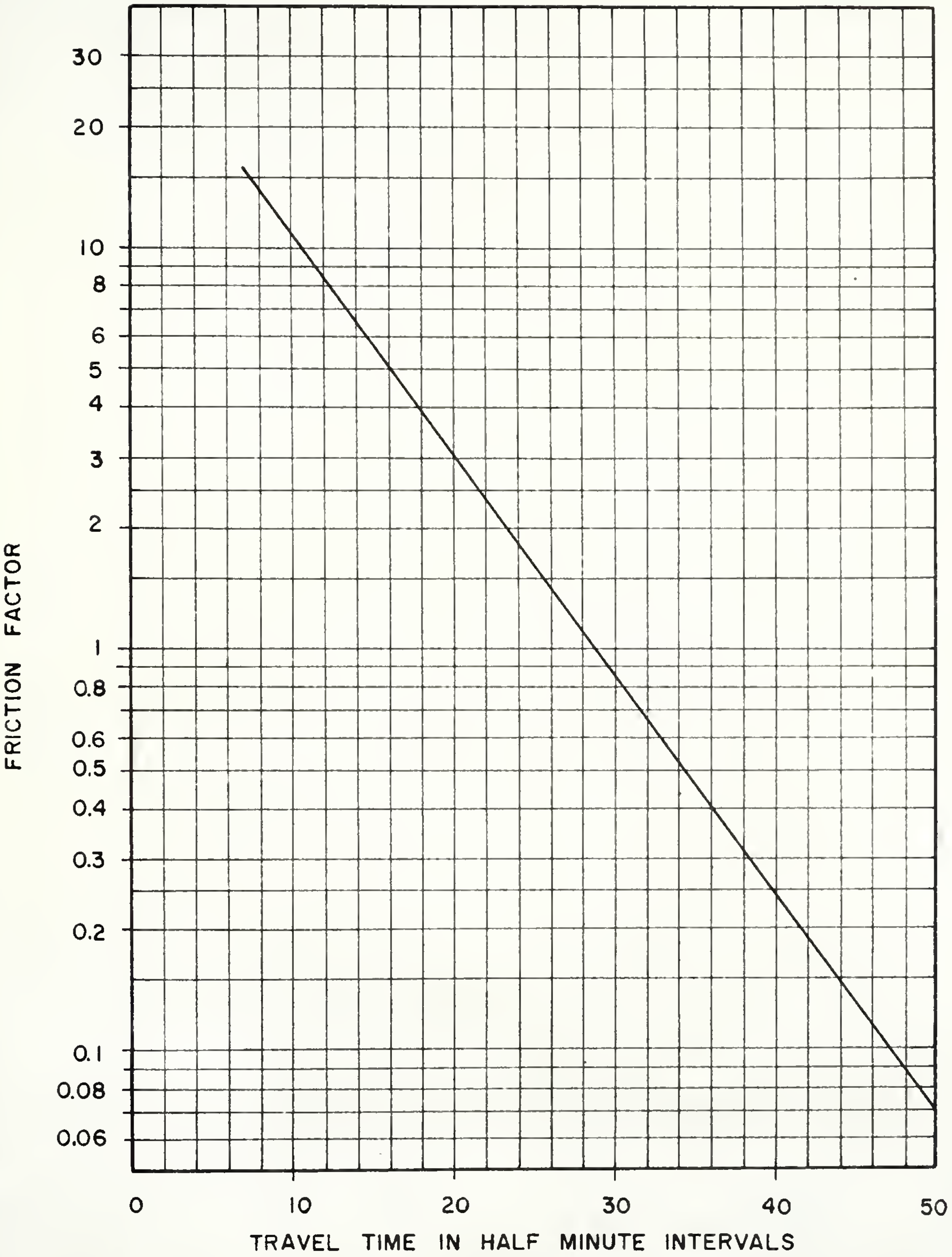


TRAVEL TIME FRICTION FACTORS WORK TRIPS

FIGURE 16

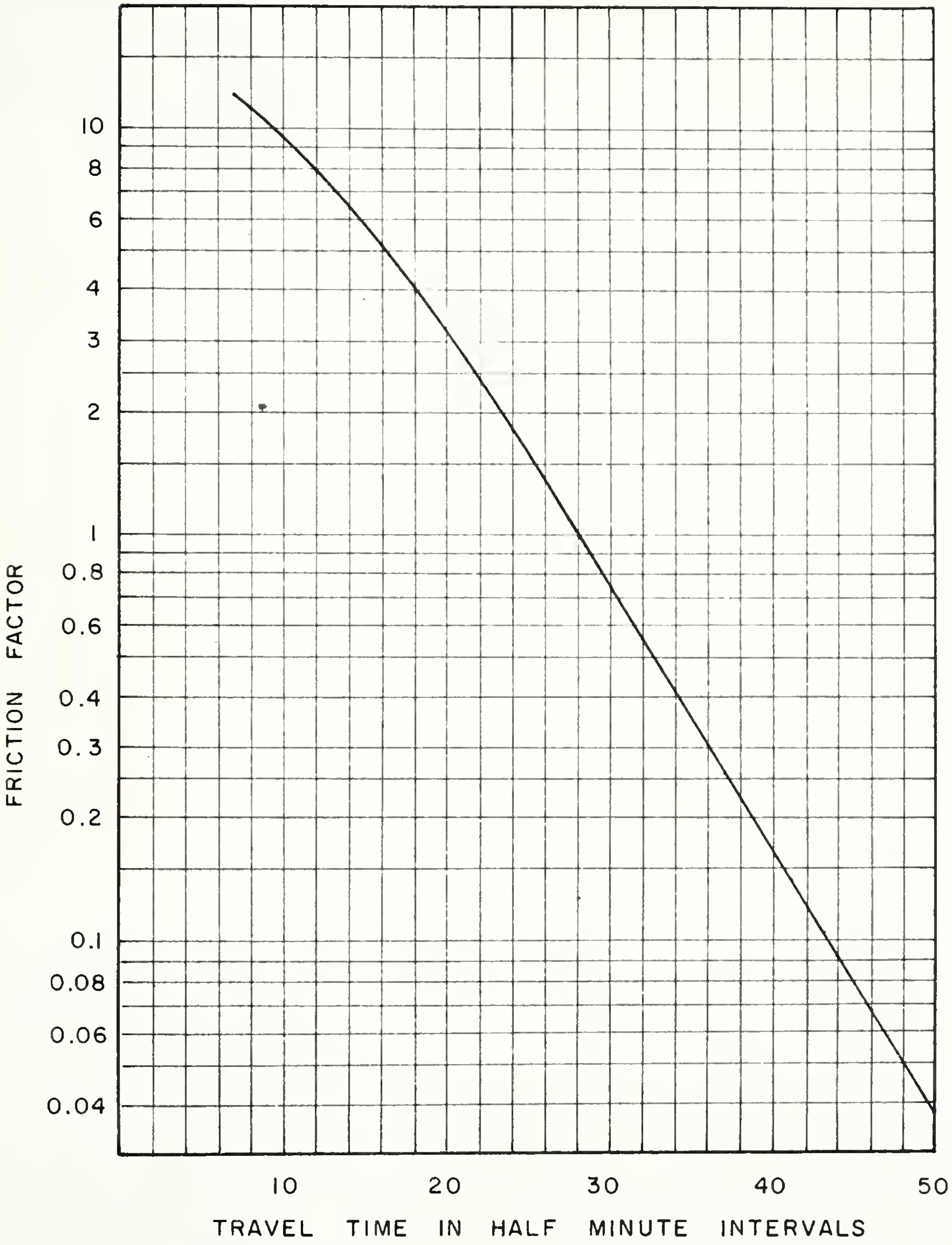


TRAVEL TIME FRICTION FACTORS COMMERCIAL TRIPS
FIGURE 17



TRAVEL TIME FRICTION FACTORS HOME-OTHER TRIPS

FIGURE 18



TRAVEL TIME FRICTION FACTORS NON-HOME TRIPS

FIGURE 19

bration. All negative values of "k" were set equal to one.

The final distribution produced fairly rational trip interchanges. This could be attributed to stratification by purpose. There was one short coming and this was due to the synthesis of trip purpose. Trips between commercial zones, between industrial zones, and between commercial and industrial zones, are lost because of present information to aid in the breakdown. These normally represent a comparatively small number of trips.

Screen line comparison

All seven distributions were linked according to trips crossing the Wabash River Screen line. The range of acceptance had been previously determined from the counting program. Only one distribution, the Fratar distribution with growth factors determined by regression analysis, was accepted. Because only one distribution was accepted, the use of the pair-wise T test was precluded.

TABLE 18

TOTAL PREDICTED RIVER CROSSINGS

METHOD	RIVER CROSSING	1953 FACTOR	1965 FACTOR
1952 Survey	20,549.00	1	0.518
1965 Count	39,688.00	1.931	1
Detroit G.F.1	159,119.38	7.743	4.009
Detroit G.F.2	44,556.04	2.168	1.123
Detroit G.F.3	35,599.10	1.732	0.897
Fratar G.F.1	131,889.70	6.418	3.323
Fratar G.F.2	56,231.10	2.736	1.417
Fratar G.F.3	36,159.14	1.760	0.911
Commercial	8,324.59		
Work	12,967.20		
Home Based	8,345.74		
Non Home Based	2,331.15		
Total	31,968.68	1.556	0.805
ACCEPTABLE RANGE	35,719 to 43,657		

In an attempt to analyze these results, a 1952 factor and a 1965 factor were calculated by dividing by the 1952 and 1965 crossings respectively. All the distributions were ranked accordingly to their deviation from one based on the 1965 factor and are:

1. FRATAR G.F.3
2. DETROIT G.F.3
3. DETROIT G.F.2
4. GRAVITY MODEL
5. FRATAR G.F.2
6. FRATAR G.F.1
7. DETROIT G.F.1

From an examination of table 18 and the above ranking, it appears quite obvious that growth factor trip distribution methods do not produce the same number of trip interchanges between specific zones with a given set of growth factors. This characteristic appears to become more pronounced as the magnitude of the growth factors increase.

Of course the number of trips predicted in the area has an effect on the screen line crossing, but this appears to be significant only when there is a very large difference. The gravity model input had more trips in the area than either Detroit G.F.3 or Fratar G.F.3 but produced fewer river crossings. This could be attributed to the

sensity of travel times for the gravity model with restriction at the bridges. The growth factor models have no provision to account for the effect of the transportation system on trip distribution.

The comparison with the screen line indicates that only Fratar G.F.3 is acceptable. If an error of up to 20% will be tolerated, then both Detroit G.F.3 and the Gravity Model distributions are acceptable. It should be noted that all three methods use regression analysis, indicating that the regression method is the best method for predicting growth.

CONCLUSIONS

The evaluation study has investigated methods of growth prediction and trip distribution. Also included in the study was the development of modified growth factor distribution methods and trip purpose synthesis. The conclusion of this investigation follow:

1. There appears to be no significant difference in the distribution of trips by purpose in any given city. The size of the city has no effect on the percentage of trips by purpose.
2. A modified growth factor distribution technique can be used to distributed trips in an area containing old zones, new zones, and zones of rapid growth.
3. Growth factors over 100 have little constructive meaning in trips distribution and most growth factors should be well below this value.
4. Trips tend to be forced between zones with growth factors of the same magnitude and restricted between zones of different magnitudes of growth factors.

5. Regression analysis appears to yield the most reasonable growth factors while arithmetic average factors are acceptable. Growth factors determined by interactance tend to be unrealistic.
6. Single purpose or uncapacitated growth factor distributions tend to produce irrational trip patterns.
7. Different growth factor methods will not produce the same trip interchanges for the same set of growth factors and the difference increases with increasing magnitude of growth factors.
8. The range in magnitude of growth factors effects the number of iterations for growth factor models.
9. Trip purpose can be synthesized for an urban area.

RECOMMENDATIONS FOR FUTURE RESEARCH

It is recommended that the following items be given thought for future investigation:

1. Development of standarized urban study zones to be used for all urban area studies.
2. Application of this study's techniques to a city which has had two comprehensive origin and destination studies so that land use and trip purpose may be studied more thoroughly and known values of trip interchanges be used for testing the update to the latest study year.
3. Adaption of capacity constraints principles to the modified growth factor models.
4. Development of additional low cost check methods in addition to screen lines.

It is recognized that not all the answers are known or will ever be known to all the question posed. But, with further inquiry in to the field a better understanding will arise and some of those questions will be answered.

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APPENDIX

APPENDIX A

Sample problems illustrating the modified Fratar distribution technique.

$$L_i = \frac{10 + 12 + 18}{(10)(3)+(12)(1.5)+(18)(1)} = \frac{40}{66} = 0.606$$

$$L_2 = \frac{(10 + 14 + 14)}{(10)(3)+(14)(1)+(14)(1.5)} = \frac{38}{65} = 0.585$$

$$L_3 = \frac{(14 + 12 + 6)}{(14)(3)+(2)(12)+(6)(1)} = \frac{32}{72} = 0.444$$

$$L_4 = \frac{(18 + 14 + 6)}{(18)(2)+(14)(3)+(6)(1.5)} = \frac{38}{87} = 0.437$$

$$L_5 = 0.01$$

$$T_{12} = (10)(2)(3)\left(\frac{0.606+0.585}{2}\right) = 35.7$$

$$T_{13} = (12)(1.5)(2)\left(\frac{0.606+0.444}{2}\right) = 18.9$$

$$T_{14} = (18)(1)(2)\left(\frac{0.606+0.437}{2}\right) = 18.8$$

$$T_{15} = (0.1)(2)(6)\left(\frac{0.606+0.01}{2}\right) = 0.4$$

$$T_{23} = (14)(3)(1.5)\left(\frac{0.585+0.444}{2}\right) = 32.4$$

$$T_{24} = (14)(1)(3)\left(\frac{0.585+0.437}{2}\right) = 21.5$$

$$T_{25} = (0.10)(6)(1.5)\left(\frac{0.585+0.01}{2}\right) = 0.3$$

$$T_{34} = (6)(1)(1.5)\left(\frac{0.437+0.444}{2}\right) = 39.6$$

APPENDIX A (cont.)

$$T_{35} = (0.10)(1.5)(6)\left(\frac{0.444+0.01}{2}\right) = 0.2$$

$$T_{45} = (0.10)(1)(6)\left(\frac{0.437+0.01}{2}\right) = 0.2$$

$$T_i' = 35.7 + 32.4 + 21.5 + 0.3 = 73.8$$

$$T_2' = 35.7 + 32.4 + 21.5 + 0.3 = 89.9$$

$$T_3' = 18.9 + 32.4 + 39.6 + 0.2 = 91.1$$

$$T_4' = 18.8 + 21.5 + 39.6 + 0.2 = 80.1$$

$$T_5' = 0.4 + 0.3 + 0.2 + 0.2 = 1.1$$

$$F_1' = \frac{80}{73.8} = 1.08$$

$$F_2' = \frac{114}{89.9} = 1.27$$

$$F_3' = \frac{48}{91.1} = 0.53$$

$$F_4' = \frac{38}{80.1} = 0.47$$

$$F_5' = \frac{40}{1.1} = 36.36$$

$$L_1' = \frac{73.8}{(1.27)(35.7)+(0.53)(18.9)+0.47)(18.8)/ +(36.36)(0.4)}$$

$$\frac{73.8}{78.83} = 0.936$$

$$L_2' = \frac{89.9}{(1.08)(35.7)+(32.4)(0.53)+(21.5)(0.47)+ (0.3)(36.36)}$$

APPENDIX A (cont.)

$$L_2' = \frac{89.9}{76.75} = 1.171$$

$$L_3' = \frac{91.1}{(18.9)(1.08)+(32.4)(1.27)+(39.6)(0.47)+(0.2)(36.36)}$$

$$\frac{91}{80.17} = 1.136$$

$$L_4' = \frac{80.1}{(18.8)(1.08)+(21.5)(1.27)+(39.6)(0.8)+(0.2)(36.36)} =$$

$$\frac{80.1}{75.87} = 1.056$$

$$L_5' = \frac{1.1}{(0.4)(1.08)+(0.3)(1.27)+(0.2)(0.53)+(0.2)(0.47)}$$

$$\frac{1.1}{1.013} = 1.086$$

$$T_{12}'' = (35.7)(1.05)(1.27)\left(\frac{0.936+1.171}{2}\right) = 51.56$$

$$T_{13}'' = (18.9)(1.08)(0.53)\left(\frac{0.936+1.136}{2}\right) = 11.76$$

$$T_{14}'' = (18.8)(1.08)(0.47)\left(\frac{0.936+1.056}{2}\right) = 9.50$$

$$T_{15}'' = (0.4)(1.08)(36.36)\left(\frac{0.936+1.086}{2}\right) = 15.88$$

$$T_{23}'' = (32.4)(1.27)(0.53)\left(\frac{1.171+1.136}{2}\right) = 25.17$$

$$T_{24}'' = (21.5)(1.27)(0.47)\left(\frac{1.171+1.056}{2}\right) = 14.28$$

APPENDIX A (cont.)

$$T''_{25} = (0.3)(1.27)(36.36)\left(\frac{1.171+1.086}{2}\right) = 15.64$$

$$T''_{34} = (39.6)(0.53)(0.47)\left(\frac{1.056+1.136}{2}\right) = 10.81$$

$$T''_{35} = (0.2)(0.53)(36.36)\left(\frac{1.136+1.086}{2}\right) = 4.28$$

$$T''_{45} = (0.2)(0.47)(36.36)\left(\frac{1.056+1.086}{2}\right) = 3.66$$

$$T''_{1} = 51.56 + 11.76 + 9.50 + 15.88 = 88.70$$

$$T''_{2} = 51.56 + 25.17 + 14.28 + 15.64 = 106.65$$

$$T''_{3} = 11.76 + 25.17 + 10.81 + 4.28 = 52.02$$

$$T''_{4} = 9.50 + 14.28 + 10.81 + 3.66 = 38.25$$

$$T''_{5} = 15.88 + 15.64 + 4.28 + 3.66 = 39.46$$

$$F''_{1} = \frac{80}{88.70} = 0.90$$

$$F''_{2} = \frac{114}{106.65} = 1.07$$

$$F''_{3} = \frac{48}{52.02} = 0.92$$

$$F''_{4} = \frac{38}{38.25} = 0.99$$

$$F''_{5} = \frac{40}{39.46} = 1.01$$

APPENDIX A (cont.)

$$L_1'' = \frac{88.70}{(1.07)(51.56)+(0.92)(11.76)+(0.99)(9.50)+(1.01)(15.88)} =$$

$$\frac{88.70}{75.39} = 1.18$$

$$L_2'' = \frac{106.65}{99.50} = 1.072$$

$$L_3'' = \frac{52.02}{(11.76)(0.90)+(25.17)(1.07)+(10.81)(0.99)+(4.28)(1.01)}$$

$$\frac{52.02}{52.53} = 0.990$$

$$L_4'' = \frac{38.25}{(9.50)(0.90)+(14.28)(1.07)+(10.81)(0.92)+(3.66)(1.01)}$$

$$\frac{38.25}{37.48} = 1.021$$

$$L_5'' = \frac{39.46}{38.58} = 1.023$$

$$T_{12}''' = (51.56)(0.90)(1.07)\left(\frac{1.180+1.072}{2}\right) = 55.91$$

$$T_{13}''' = (11.76)(0.90)(0.92)\left(\frac{1.180+0.990}{2}\right) = 10.68$$

$$T_{14}''' = (9.50)(0.90)(0.99)\left(\frac{1.180+1.021}{2}\right) = 9.31$$

$$T_{15}''' = (15.88)(0.90)(1.01)\left(\frac{1.180+1.023}{2}\right) = 15.89$$

$$T_{23}''' = (25.17)(1.07)(0.92)\left(\frac{1.072+0.990}{2}\right) = 25.52$$

APPENDIX A (cont.)

$$T'''_{24} = (14.28)(1.07)(0.99)\left(\frac{1.072+1.021}{2}\right) = 15.82$$

$$T'''_{25} = (15.64)(1.07)(1.01)\left(\frac{1.072+1.023}{2}\right) = 17.70$$

$$T'''_{34} = (10.81)(0.92)(0.99)\left(\frac{0.990+1.021}{2}\right) = 9.90$$

$$T'''_{35} = (4.28)(0.92)(1.01)\left(\frac{0.990+1.023}{2}\right) = 4.00$$

$$T'''_{45} = (3.66)(0.99)(1.01)\left(\frac{1.021+1.023}{2}\right) = 3.74$$

$$T'''_{1} = 55.91 + 10.68 + 9.31 + 15.39 = 91.79$$

$$T'''_{2} = 55.91 + 25.52 + 15.82 + 17.70 = 114.95$$

$$T'''_{3} = 10.68 + 25.52 + 4.90 + 4.00 = 50.10$$

$$T'''_{4} = 9.31 + 15.82 + 9.90 + 3.74 = 38.77$$

$$T'''_{5} = 15.89 + 17.70 + 4.00 + 3.74 = 41.33$$

$$F'''_{1} = \frac{80}{91.79} = 0.87$$

$$F'''_{2} = \frac{114}{114.95} = 0.99$$

$$F'''_{3} = \frac{48}{50.10} = 0.95$$

$$F'''_{4} = \frac{38}{38.77} = 0.98$$

APPENDIX A (cont.)

$$F'''_{5} = \frac{40}{41.33} = 0.97$$

$$L''''_{1} = \frac{91.79}{90.14} = 1.018$$

$$L''''_{2} = \frac{114.95}{(55.91)(0.87)+(25.52)(0.96)+(15.82)/(0.98)+(17.70)((0.97)}$$

$$\frac{114.95}{105.91} = 1.086$$

$$L''''_{3} = \frac{50.10}{(10.68)(0.87)+(25.52)(0.99)+(9.90)/(0.98)+(4.0)(0.97)}$$

$$\frac{50.10}{48.1} = 1.042$$

$$L''''_{4} = \frac{38.77}{(9.31)(0.87)+(15.82)(0.99)+(9.90)(0.98)+/(3.75)(0.97)}$$

$$\frac{38.77}{36.90} = 1.051$$

$$L''''_{5} = \frac{41.33}{(15.89)(0.87)+(17.70)(0.99)+(4.00)(0.96)+/(3.74)(0.98)}$$

$$\frac{41.33}{38.85} = 1.064$$

$$T''''_{12} = (55.91)(0.87)(0.99)\ \frac{1.018+1.086}{2} = 53.60$$

$$T''''_{13} = (10.68)(0.87)(0.96)\ \frac{1.018+1.042}{2} = 9.20$$

$$T''''_{14} = (9.31)(0.87)(0.98)\ \frac{1,018+1.051}{2} = 8.30$$

APPENDIX A (cont.)

$$T''''_{15} = (15.89)(0.87)(0.97)\ \frac{1.018+1.064}{2} = 14.13$$

$$T''''_{23} = (25.52)(0.99)(0.96)\ \frac{1.086+1.042}{2} = 26.10$$

$$T''''_{24} = (15.82)(0.99)(0.97)\ \frac{1.086+1.051}{2} = 16.41$$

$$T''''_{25} = (17.70)(0.99)(0.97)\ \frac{1.086+1.064}{2} = 18.48$$

$$T''''_{34} = (9.90)(0.96)(0.98)\ \frac{1.086+1.051}{2} = 9.73$$

$$T''''_{35} = (4.00)(0.96)(0.98)\ \frac{1.042+1.051}{2} = 3.93$$

$$T''''_{45} = (3.74)(0.98)(0.97)\ \frac{1.051+1.064}{2} = 3.80$$

$$T''''_{1} = 53.60 + 9.20 + 8.30 + 14.13 = 85.23$$

$$T''''_{2} = 53.60 + 26.10 + 16.41 + 18.48 = 114.59$$

$$T''''_{3} = 9.20 + 26.10 + 9.73 + 3.73 = 48.96$$

$$T''''_{4} = 14.13 + 18.48 + 3.93 + 3.80 = 38.24$$

$$T''''_{5} = 14.13 + 18.48 + 3.93 + 3.80 = 40.34$$

$$F''''_{1} = \frac{80}{85.23} = 0.94$$

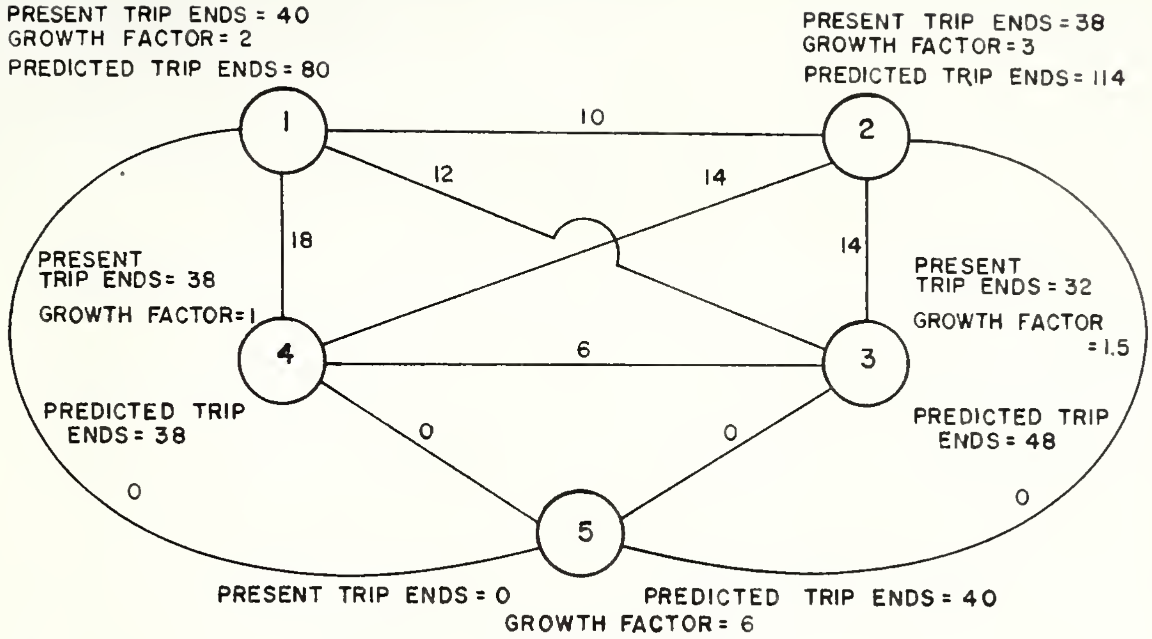
$$F''''_{2} = \frac{114}{114.59} = 0.99$$

APPENDIX A (cont.)

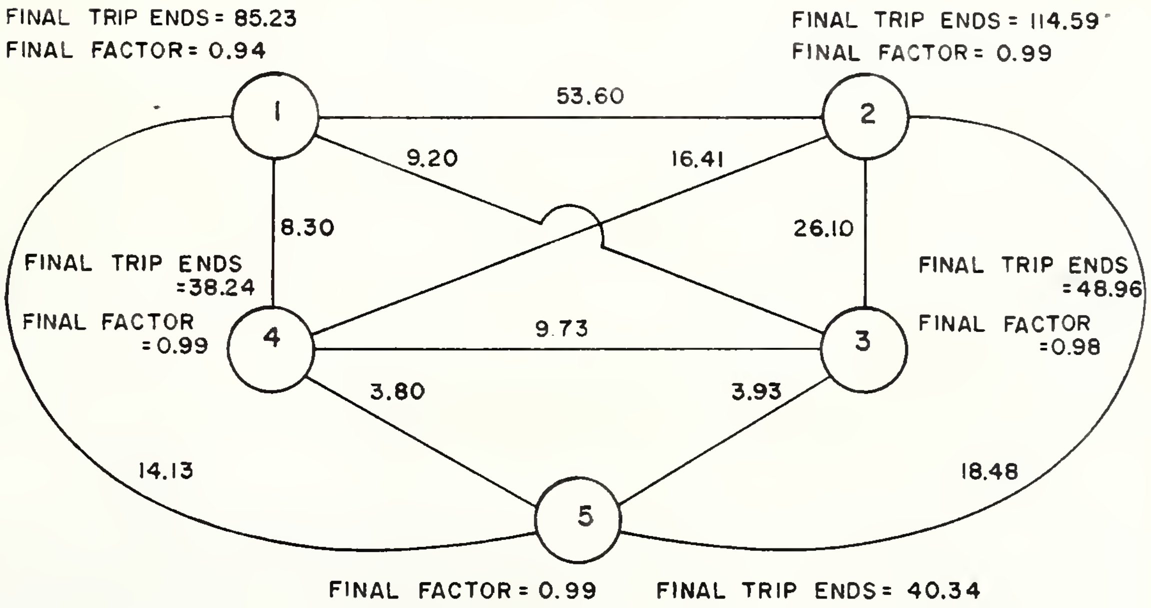
$$F''''_3 = \frac{48}{48.96} = 0.98$$

$$F''''_4 = \frac{38}{38.24} = 0.99$$

$$F''''_5 = \frac{40}{40.34} = 0.99$$



ORIGINAL TRIP DISTRIBUTION



FUTURE TRIP DISTRIBUTION

EXAMPLE PROBLEM - MODIFIED FRATAR DISTRIBUTION

FIGURE A-1

APPENDIX B

Sample problem illustrating the modified Detroit distribution technique.

Iteration 1:

$$G = \frac{80+114+48+38+30}{148} = \frac{310}{148} = 2.09$$

$$T_{12} = \frac{(10)(2)(3)}{(2.09)} = \quad = 28.71$$

$$T_{13} = (12)\frac{(2)(1.5)}{2.09} = 17.22$$

$$T_{14} = (18)\frac{(2)(1)}{2.09} = 17.22$$

$$T_{15} = (0.1)\frac{(10)(2)}{2.09} = 0.96$$

$$T_{23} = (14)\frac{(3)(1.5)}{2.09} = 30.14$$

$$T_{24} = \frac{(14)(3)(1)}{2.09} = 20.10$$

$$T_{25} = \frac{(0.1)(3)(10)}{2.09} = 1.44$$

$$T_{34} = \frac{(6)(1.5)(1)}{2.09} = 4.31$$

$$T_{35} = \frac{(0.1)(1.5)(10)}{2.09} = 0.72$$

APPENDIX E (cont.)

$$T_{45} = \frac{(0.1)(10)(1)}{2.09} = 0.478$$

$$T_{1} = 28.71 + 17.22 + 17.22 + 0.96 = 64.11$$

$$T_{2} = 28.71 + 30.14 + 20.10 + 1.44 = 80.39$$

$$T_{3} = 17.22 + 30.14 + 4.31 + 0.72 = 52.39$$

$$T_{4} = 17.22 + 20.10 + 4.31 + 0.478 = 42.11$$

$$T_{5} = 0.96 + 1.44 + 0.72 + 0.478 = 3.60$$

$$G_{1}' = \frac{80}{64.11} = 1.25$$

$$G_{2}' = \frac{114}{80.39} = 1.42$$

$$G_{3}' = \frac{48}{52.39} = 0.92$$

$$G_{4}' = \frac{38}{42.11} = 0.90$$

$$G_{5}' = \frac{30}{3.60} = 8.33$$

$$G = \frac{310}{64.11+80.39+52.39+42.11+3.60} = \frac{310}{242.60} = 1.28$$

$$T_{12}' = (28.71) \frac{(1.25)(1.42)}{(1.28)} = 39.81$$

APPENDIX B (cont.)

$$T'_{13} = (17.22) \frac{(1.25)(0.92)}{(1.28)} = 14.23$$

$$T'_{14} = \frac{(17.22)(1.25)(0.90)}{(1.28)} = 15.13$$

$$T'_{15} = (0.96) \frac{(1.25)(8.33)}{(1.28} = 7.81$$

$$T'_{23} = (30.14) \frac{(1.42)(0.92)}{(1.28)} = 30.76$$

$$T'_{24} = (20.10) \frac{(1.42)(0.90)}{(1.28)} = 20.06$$

$$T'_{25} = (1.44) \frac{(1.42)(8.33)}{(1.28)} = 13.31$$

$$T'_{34} = (4.31) \frac{(0.92)(0.90)}{(1.28)} = 2.79$$

$$T'_{35} = (0.72) \frac{(0.92)(8.33)}{(1.28)} = 4.31$$

$$T'_{45} = (0.48) \frac{(0.90)(8.33)}{(1.28)} . = 2.81$$

$$T'_{1} = 39.81 + 14.23 + 15.13 + 7.81 = 76.98$$

$$T'_{2} = 39.81 + 30.76 + 20.06 + 13.31 = 103.94$$

APPENDIX B (cont.)

$$T_3{}' = 14.23 + 30.76 + 2.79 + 4.31 \quad = \quad 52.09$$

$$T_4{}' = 15.13 + 20.06 + 2.79 + 2.81 \quad = \quad 40.97$$

$$T_5{}' = 7.81 + 13.31 + 4.31 + 2.81 \quad = \quad 28.24$$

$$T' = 302.22$$

$$G_1{}' = \frac{80}{76.98} \quad = \quad 1.04$$

$$G_2{}' = \frac{114}{103.94} \quad = \quad 1.10$$

$$G_3{}' = \frac{48}{52.09} \quad = \quad 0.92$$

$$G_4{}' = \frac{38}{40.97} \quad = \quad 0.93$$

$$G_5{}' = \frac{30}{28.24} \quad = \quad 1.06$$

$$G' = \frac{310}{302.22} \quad = \quad 1.03$$

$$T_{12}{}'' = (39.81) \quad \frac{(1.04)(1.10)}{(1.03)} \quad = \quad 44.22$$

$$T_{13}{}'' = (14.23) \quad \frac{(1.04)(0.92)}{(1.03)} \quad = \quad 13.22$$

APPENDIX B (cont.)

$$T_{14}'' = (15.13)\,\frac{(1.04)(0.93)}{(1.03)} = 14.21$$

$$T_{15}'' = (7.81)\,\frac{(1.04)(1.06)}{(1.03)} = 8.36$$

$$T_{23}'' = (30.76)\,\frac{(1.10)(0.92)}{(1.03)} = 30.22$$

$$T_{24}'' = (20.06)\,\frac{(1.10)(0.93)}{(1.03)} = 19.92$$

$$T_{25}'' = (13.31)\,\frac{(1.10)(1.06)}{(1.03)} = 15.07$$

$$T_{34}'' = (2.79)\,\frac{(0.92)(0.93)}{(1.03)} = 2.34$$

$$T_{35}'' = (4.31)\,\frac{(0.92)(1.06)}{(1.03)} = 4.08$$

$$T_{45}'' = (2.81)\,\frac{(0.93)(1.06)}{(1.03)} = 2.69$$

$$T_{1}'' = 44.32 + 13.22 + 14.21 + 8.36 = 80.11$$

$$T_{2}'' = 44.32 + 30.22 + 19.92 + 15.07 = 109.53$$

$$T_{3}'' = 13.22 + 30.22 + 2.34 + 4.08 = 49.86$$

APPENDIX B (cont.)

$$T''_4 = 14.21 + 19.92 + 2.34 + 2.69 = 39.16$$

$$T''_5 = 8.36 + 15.07 + 4.08 + 2.69 = 30.20$$

$$T'' = 308.86$$

$$G''_1 = 80/80.11 = 0.99$$

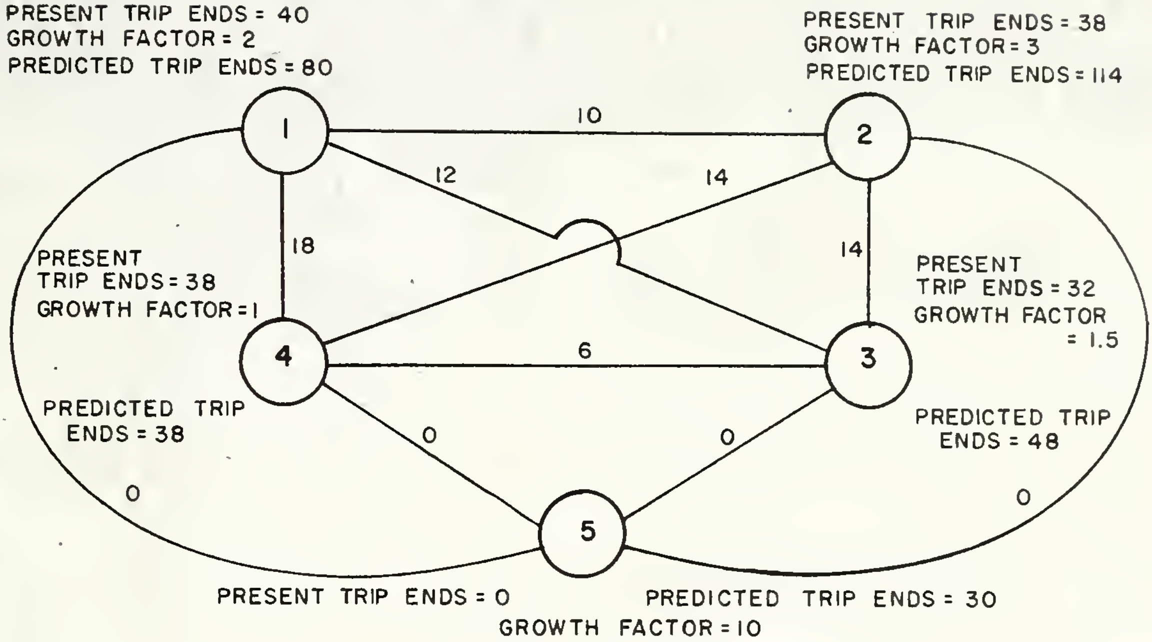
$$G''_2 = \frac{114}{109.53} = 1.04$$

$$G''_3 = \frac{48}{49.86} = 0.96$$

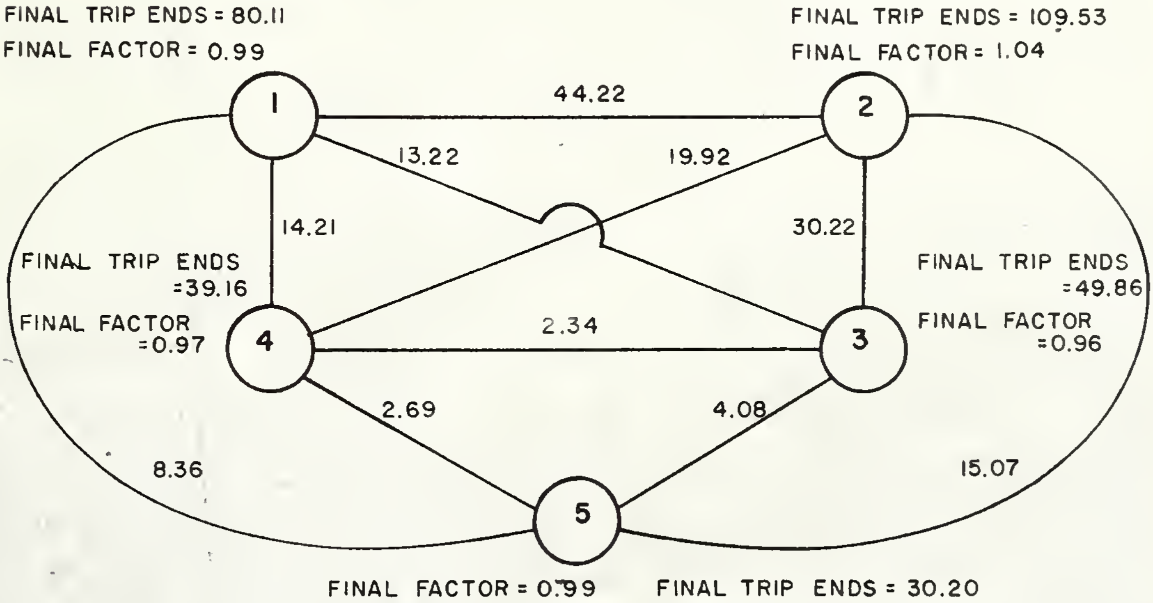
$$G''_4 = \frac{38}{39.16} = 0.97$$

$$G''_5 = \frac{30}{30.20} = 0.99$$

$$G = \frac{310}{308.86} = 1.003$$



ORIGINAL TRIP DISTRIBUTION



FUTURE TRIP DISTRIBUTION

EXAMPLE PROBLEM - MODIFIED DETROIT DISTRIBUTION

FIGURE B-1

TABLE C-1

Study Zone Data

Zone	1950 Pop.	1960 Pop.	1952 Dwellings	1964 Dwellings	1956 Auto. Reg.	1964 Auto Reg.	1952 Trip Ends	Area in Acres
1	6	18	2	5	0	1	210	131.2
2	37	37	11	11	14	32	80	278.3
3	79	75	1	16	0	34	402	80.6
4	79	152	26	49	18	83	3402	120.6
5	639	1666	308	477	606	715	3402	240.2
6	738	1295	238	280	395	407	3209	115.9
7	-	-	-	-	3	3	679	61.6
8	652	796	227	297	168	161	1763	101.0
9	53	1274	16	21	4	34	60	213.6
10	1548	1119	0	2	44	20	2832	33.8
11	1612	1957	130	98	179	111	2838	44.1
12	998	2318	97	79	182	159	2973	51.4
13	-	-	36	17	44	20	12808	88.4
14	1636	1043	397	379	484	498	4877	78.1

TABLE C-1 (cont.)

Zone	1950 Pop.	1960 Pop.	1952 Dwellings	1964 Dwellings	1956 Auto. Reg.	1964 Auto. Reg.	1952 Trip Ends	Area in Acres
15	1272	1170	340	526	465	480	2795	206.8
16	1630	1859	322	313	489	428	5441	91.4
17	52	67	20	9	75	56	3150	86.6
18	446	296	142	107	177	91	4804	15.6
19	2656	2052	398	454	460	567	3632	121.5
20	-	-	-	-	12	20	3262	79.3
21	1294	2919	635	1164	399	763	2228	124.1
22	-	-	-	-	1	4	1148	168.3
23	-	-	-	-	0	0	52	224.6
24	-	-	-	-	0	3	133	257.5
25	-	4	-	1	2	25	0	25.3
26	-	14	-	4	0	11	0	24.3
27	-	562	2	152	1	123	0	73.6
28	15	101	3	30	2	63	0	102.2
29	-	136	2	34	0	22	0	102.9
30	358	408	113	61	146	165	661	76.3

TABLE C-1 (contd.)

Zone	1950 Pop.	1960 Pop.	1952 Dwellings	1964 Dwellings	1956 Auto. Reg.	1964 Auto. Reg.	1952 Trip Ends	Area in Acres
31	734	383	158	172	174	144	702	41.1
32	249	193	11	4	34	13	540	33.0
33	992	746	373	283	361	276	2397	54.0
34	1432	1088	417	333	375	414	3046	64.8
35	92	134	72	43	138	118	7414	13.2
36	140	64	6	3	174	139	13300	27.6
37	99	25	13	2	32	45	2185	18.3
38	572	176	30	12	49	55	1430	25.1
39	1211	1170	544	377	505	318	4560	48.8
40	1756	1287	515	455	514	401	5727	64.6
41	1698	1500	459	392	455	414	3980	73.5
42	1437	1457	423	377	436	398	3787	74.1
43	114	51	24	16	53	47	954	80.9
44	-	6	4	2	12	13	1317	12.7
45	1689	1503	543	502	541	585	3238	110.9
46	1337	1313	329	310	325	366	1902	65.1

TABLE C-1 (cont.)

Zone	1950 Pop.	1960 Pop.	1952 Dwellings	1964 Dwellings	1956 Auto. Reg.	1964 Auto. Reg.	1952 Trip Ends	Area in Acres
47	57	17	6	5	24	16	267	100.5
48	47	51	14	17	32	7	72	390.3
49	-	-	-	-	0	0	731	75.0
50	128	55	9	11	16	19	1467	76.9
51	1133	1114	323	309	398	405	2026	82.2
52	1101	899	363	304	404	429	1911	77.3
53	1158	1670	393	425	549	617	1914	99.3
54	95	48	-	15	1	3	611	193.8
55	504	2116	495	683	819	937	2944	197.3
56	-	142	36	40	12	36	1346	116.4
57	143	898	111	234	185	318	803	171.3
58	1117	1167	272	295	319	340	1993.5	143.2
59	1611	1559	426	342	446	431	3944	137.0
60	1098	1372	383	270	430	455	2191	67.9
61	1367	1263	405	383	487	494	3872	105.7
62	561	586	164	133	167	195	3133	76.8

TABLE C-1 (cont.)

Zone	1950 Pop.	1960 Pop.	1952 Dwellings	1964 Dwellings	1956 Auto. Reg.	1964 Auto. Reg.	1952 Trip Ends	Area in Acres
63	1305	1214	450	406	455	479	2071	82.2
64	16	25	5	7	30	42	1529	140.1
65	7	7	2	2	0	7	501	59.0
66	1118	1151	403	407	465	535	2267	80.6
67	17	13	5	4	114	23	2013	109.7
68	1866	1784	474	515	621	725	2339	134.6
69	780	841	369	302	371	447	1710	78.0
70	1462	1593	496	461	566	560	3245	90.3
71	767	893	189	201	264	277	1717	70.0
72	884	755	249	217	298	319	1685	72.3
73	956	793	225	201	248	279	949	143.0
74	718	721	251	245	292	353	1563	78.8
75	229	51	44	44	85	92	387.5	106.2
76	1398	1908	517	540	611	683	3083	138.5
77	89	233	13	22	31	44	662	216.2
78	-	-	-	-	3	2	2083	145.7

TABLE C-1 (cont.)

Zone	1950 Pop.	1960 Pop.	1952 Dwellings	1964 Dwellings	1956 Auto. Reg.	1964 Auto. Reg.	1952 Trip Ends	Area in Acres
79	-	-	4	-	0	1	0	35.9
80	-	18	-	5	1	0	743	193.1
81	88	162	22	45	3	20	0	128.6
82	103	428	25	69	97	133	232.5	161.0
83	20	496	8	133	1	120	0	212.9
84	115	4584	29	1025	483	1516	0	244.1
85	3	308	1	76	3	91	155.0	166.5
86	11	2307	3	556	3	1009	0	269.2
87	9	164	3	41	0	46	0	229.8
88	13	21	4	6	14	20	0	242.3
89	18	35	5	10	0	5	0	176.8
90	30	28	8	8	0	0	0	66.1
91	83	176	25	47	3	43	0	420.6
92	8	11	3	3	4	12	0	479.9
93	13	39	4	11	5	21	0	170.9
94	85	599	25	146	152	192	0	217.9

TABLE C-1 (cont.)

Zone	1950 Pop.	1960 Pop.	1952 Dwellings	1964 Dwellings	1956 Auto. Reg.	1964 Auto. Reg.	1952 Trip Ends	Area in Acres
95	16	227	7	64	1	106	0	411.5
96	248	759	-	112	0	152	0	45.6
97	64	121	17	35	26	30	221.5	54.7
98	-	12	1	3	0	1	0	13.8
99	20	344	7	84	1	63	0	131.8
100	11	56	3	14	1	33	0	111.5
101	-	-	-	-	1	2	0	91.1
102	-	-	-	-	0	0	0	76.7
103	10	300	3	122	56	169	0	101.3
104	-	676	-	245	1	375	0	224.2
105	-	7	-	2	1	1	18.9	70.9
106	-	225	-	49	36	107	18.9	76.4

TABLE C-2

Commercial Zone Data

Zone	1953 Employees	1954 Employees	1953 Est.	1964 Est.
3	15	121	4	18
17	290	756	50	42
18	403	427	68	65
22	20	30	1	2
25	0	65	0	10
26	0	65	0	5
35	2037	1488	204	168
36	3547	2865	398	329
37	502	290	53	44
38	175	230	22	20
54	90	126	9	10
77	20	453	1	24
79	0	168	0	1
97	2	479	1	29
102	0	101	0	8

TABLE C-3

Industrial Zone Data

Zone	1953 Employees	1964 Employees	1953 Est.	1964 Est.
23	55	50	1	1
24	16	52	1	4
30	197	150	18	12
32	72	69	8	6
43	116	223	12	13
44	1040	1148	2	2
47	68	82	6	11
48	113	341	6	18
49	620	541	1	2
50	158	110	8	9
56	818	201	13	22
64	287	645	26	60
65	202	552	7	20
67	1279	1538	17	32
78	3155	2230	1	1
80	529	1205	1	3
88	0	315	0	15
101	0	755	0	9

TABLE C-4

ORIGINAL 1952 ZONES

(Refer to Fig.3)

ZONE NUMBERS

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TABLE C-5

1964 STUDY ZONES

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TABLE D-1

DETROIT DISTRIBUTION GROWTH FACTOR ONE

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
1	1559.52	1.000
2	160.28	0.998
3	14751.56	1.002
4	5669.10	1.000
5	16049.68	1.010
6	6581.51	1.009
7	1334.25	1.006
8	2664.16	1.012
9	16143.52	0.998
10	2395.01	1.014
11	1593.01	1.013
12	4835.92	1.012
13	25005.69	1.012
14	2964.55	1.010
15	4071.21	1.009
16	4387.38	1.003
17	6832.56	1.008
18	4815.10	1.010
19	3923.73	1.010
20	6345.06	1.013
21	17510.33	1.007
22	3470.85	1.003
23	47.38	0.998
24	1667.15	0.998
25	1019.94	0.997
26	819.65	0.997
27	694.14	0.997
28	1012.12	0.997
29	1140.74	0.997
30	306.40	0.996
31	329.24	0.996
32	387.96	1.001
33	1067.56	0.986
34	2045.96	1.000
35	4454.35	1.001
36	8916.41	0.996
37	1056.82	0.992
38	1723.26	0.993
39	1925.25	1.002
40	3027.01	0.996

TABLE D-I (CONT.)

DETROIT DISTRIBUTION GROWTH FACTOR ONE

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
41	2894.99	0.999
42	3116.48	1.003
43	1963.99	1.003
44	1450.67	1.002
45	2877.85	0.999
46	1907.76	0.992
47	592.77	0.999
48	680.75	0.998
49	1271.89	1.003
50	1145.13	0.995
51	1954.22	0.993
52	1396.07	0.994
53	3361.32	0.996
54	965.57	0.991
55	19666.02	0.991
56	561.24	0.994
57	18300.29	1.001
58	2411.08	1.004
59	2976.39	0.993
60	2055.17	0.995
61	3436.39	0.996
62	3118.74	0.994
63	1840.64	0.997
64	7979.52	0.990
65	3965.65	0.986
66	2740.51	0.996
67	4526.49	0.995
68	2854.26	0.994
69	1845.89	0.985
70	3259.18	0.991
71	2225.58	1.003
72	1350.29	0.994
73	798.53	0.993
74	1866.21	0.992
75	102.61	0.984
76	4995.92	0.984
77	366083.17	1.008
78	1479.65	0.995
79	3516.83	0.997
80	5075.28	1.002

TABLE D-I (CONT.)

DETROIT DISTRIBUTION GROWTH FACTOR ONE

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
81	1152.72	0.997
82	3539.24	0.986
83	2090.69	0.997
84	10541.00	0.997
85	148843.53	0.988
86	5114.11	0.997
87	2080.32	0.997
88	1610.07	0.997
89	1538.49	0.997
90	571.47	0.997
91	3723.16	0.997
92	4173.58	0.997
93	1520.43	0.997
94	2285.17	0.997
95	3773.66	0.997
96	1124.34	0.997
97	220210.81	0.995
98	121.77	0.997
99	1271.95	0.997
100	1030.71	0.997
101	1115.06	0.997
102	2315.38	0.997
103	1233.32	0.997
104	2732.00	0.997
105	18.05	0.997
106	29084.71	0.997

DETROIT DISTRIBUTION GROWTH FACTOR TWO

TABLE D-2

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
1	451.45	0.998
2	161.59	0.990
3	2557.80	1.000
4	953.84	0.998
5	5984.41	1.011
6	4070.62	1.013
7	1333.46	1.006
8	2015.16	1.017
9	482.49	0.989
10	3072.57	1.017
11	2417.11	1.015
12	3906.58	1.014
13	24952.29	1.014
14	4115.64	1.014
15	3217.40	1.013
16	4925.92	1.013
17	5378.69	1.008
18	4781.05	1.013
19	3787.25	1.010
20	6342.16	1.014
21	4389.47	1.016
22	2007.13	1.011
23	50.26	0.988
24	468.18	0.991
25	1031.56	0.986
26	829.00	0.986
27	702.07	0.986
28	1023.66	0.986
29	1153.73	0.986
30	431.11	0.995
31	577.08	0.996
32	460.09	0.998
33	1829.14	1.000
34	2703.90	1.003
35	5735.38	1.003
36	10827.72	1.005
37	1536.45	1.001
38	1591.69	1.001
39	3471.30	1.004
40	4759.64	1.002

DETROIT DISTRIBUTION GROWTH FACTOR TWO
TABLE D-2 (CONT.)

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
41	3715.18	1.001
42	3548.36	1.002
43	1421.70	1.000
44	1387.63	0.998
45	3115.36	1.002
46	1932.98	1.000
47	409.56	0.994
48	228.40	0.988
49	1054.63	0.996
50	1325.80	1.000
51	1996.70	1.000
52	1730.33	0.999
53	2322.31	1.000
54	774.84	0.997
55	6588.34	1.001
56	1300.16	0.999
57	2713.70	0.999
58	2125.04	1.003
59	3452.91	1.002
60	2202.78	1.001
61	3705.60	1.002
62	3155.96	1.000
63	1998.32	1.001
64	3475.30	0.999
65	1156.55	0.994
66	2415.95	1.001
67	3071.09	1.000
68	2500.88	1.001
69	1773.61	0.997
70	3232.31	1.001
71	1877.08	1.000
72	1571.55	1.000
73	904.52	0.998
74	1659.97	1.001
75	324.23	0.992
76	3639.34	0.997
77	15941.31	0.993
78	1782.80	0.998
79	2285.25	0.987
80	1969.80	0.997

DETROIT DISTRIBUTION GROWTH FACTOR TWO

TABLE D-2 (CONT.)

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
81	1165.85	0.986
82	618.60	0.991
83	2114.34	0.986
84	10653.13	0.987
85	10343.71	0.990
86	5170.77	0.986
87	2103.86	0.986
88	1628.35	0.986
89	1555.96	0.986
90	578.00	0.986
91	3764.81	0.986
92	4220.12	0.986
93	1537.70	0.986
94	2310.99	0.986
95	3815.87	0.986
96	1137.15	0.986
97	29610.04	0.993
98	123.17	0.986
99	1286.42	0.986
100	1042.45	0.986
101	1127.76	0.986
102	2341.54	0.986
103	1247.35	0.986
104	2762.78	0.986
105	18.26	0.986
106	2714.17	0.986

TABLE D-3

DETROIT DISTRIBUTION GROWTH FACTOR THREE

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
1	209.24	0.996
2	161.72	0.989
3	494.78	0.998
4	382.04	0.996
5	3909.84	1.006
6	3780.86	1.006
7	1339.89	1.001
8	1771.89	1.007
9	63.03	0.989
10	942.22	1.007
11	2428.49	1.006
12	7857.32	1.006
13	25123.85	1.007
14	3212.22	1.007
15	2786.39	1.006
16	5353.89	1.007
17	2917.80	1.005
18	4596.02	1.007
19	3309.93	1.006
20	6386.71	1.006
21	6553.26	1.007
22	1163.92	1.005
23	52.60	0.989
24	129.72	0.991
25	1031.57	0.986
26	829.01	0.986
27	702.08	0.986
28	1023.67	0.986
29	1153.74	0.986
30	474.40	0.997
31	426.18	0.998
32	480.04	0.998
33	1546.16	1.002
34	2478.26	1.003
35	6136.15	1.004
36	11054.83	1.005
37	1887.90	1.002
38	1360.96	1.001
39	2890.71	1.004
40	3265.09	1.004

TABLE. D-3 (CONT.)

DETROIT DISTRIBUTION GROWTH FACTOR THREE

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
41	3370.63	1.003
42	3563.27	1.003
43	1161.88	1.000
44	1445.30	1.001
45	3134.53	1.003
46	2045.85	1.002
47	285.52	0.994
48	79.30	0.988
49	797.49	0.998
50	1387.18	1.001
51	2024.64	1.001
52	1751.76	1.001
53	2706.73	1.001
54	619.81	0.998
55	4023.29	1.003
56	951.37	1.001
57	960.20	0.999
58	2069.10	1.002
59	3793.41	1.003
60	2857.41	1.003
61	3715.84	1.003
62	3355.31	1.003
63	2035.52	1.002
64	3592.90	1.001
65	1662.14	0.997
66	2577.89	1.002
67	3725.96	1.001
68	2521.93	1.002
69	1994.83	1.001
70	3447.84	1.003
71	1904.52	1.002
72	1627.60	1.002
73	970.70	0.999
74	1743.52	1.001
75	424.54	0.996
76	3902.68	1.003
77	775.20	0.998
78	1994.82	1.001
79	1015.11	0.987
80	818.94	0.998

TABLE D-3 (CONT.)

DETROIT DISTRIBUTION GROWTH FACTOR THREE

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
81	1165.86	0.986
82	235.00	0.993
83	2114.35	0.986
84	10652.31	0.987
85	166.93	0.991
86	5170.70	0.986
87	2103.86	0.986
88	1628.36	0.986
89	1555.97	0.986
90	578.00	0.986
91	3764.79	0.986
92	4220.09	0.986
93	1537.71	0.986
94	2311.00	0.986
95	3815.85	0.986
96	1137.15	0.986
97	364.38	0.993
98	123.17	0.986
99	1286.43	0.986
100	1042.46	0.986
101	1127.77	0.986
102	2341.54	0.986
103	1247.36	0.986
104	2762.78	0.986
105	18.26	0.986
106	35.55	0.986

TABLE D-4

FRATAR DISTRIBUTION GROWTH FACTOR ONE

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
1	1562.89	0.998
2	160.62	0.996
3	14787.46	0.999
4	5685.54	0.997
5	16140.77	1.004
6	6648.70	0.999
7	1340.25	1.001
8	2696.22	1.000
9	16182.16	0.996
10	2423.48	1.002
11	1609.35	1.003
12	4879.19	1.003
13	25292.86	1.000
14	3005.56	0.997
15	4119.30	0.997
16	4434.74	0.992
17	6865.58	1.003
18	4861.83	1.000
19	3943.17	1.005
20	6396.44	1.005
21	17824.39	0.989
22	3515.03	0.990
23	47.50	0.995
24	1668.70	0.997
25	1016.44	1.001
26	816.84	1.001
27	691.76	1.001
28	1008.65	1.001
29	1136.82	1.001
30	306.89	0.995
31	332.45	0.986
32	388.25	1.000
33	1069.01	0.985
34	2050.87	0.998
35	4464.45	0.999
36	8951.80	0.992
37	1058.46	0.991
38	1727.88	0.990
39	1934.02	0.997
40	3031.03	0.994

TABLE D-4 (CONT.)

FRATAR DISTRIBUTION GROWTH FACTOR ONE

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
41	2896.90	0.998
42	3122.44	1.001
43	1961.90	1.004
44	1451.76	1.002
45	2884.65	0.997
46	1910.79	0.991
47	593.49	0.998
48	681.20	0.997
49	1269.18	1.006
50	1153.69	0.987
51	1967.60	0.986
52	1397.38	0.993
53	3373.08	0.992
54	967.48	0.989
55	19674.31	0.991
56	562.17	0.992
57	18249.14	1.004
58	2434.71	0.994
59	2982.36	0.991
60	2057.92	0.994
61	3449.22	0.992
62	3124.79	0.992
63	1847.50	0.994
64	7984.62	0.990
65	3977.92	0.983
66	2747.89	0.994
67	4532.27	0.994
68	2868.39	0.989
69	1846.07	0.985
70	3265.95	0.988
71	2235.20	0.998
72	1353.00	0.992
73	798.21	0.994
74	1874.24	0.988
75	102.75	0.983
76	4999.73	0.983
77	364233.29	1.013
78	1480.65	0.995
79	3521.90	0.996
80	5056.05	1.006

TABLE D-4 (CONT.)

FRATAR DISTRIBUTION GROWTH FACTOR ONE

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
81	1148.77	1.001
82	3549.65	0.983
83	2083.50	1.001
84	10504.58	1.001
85	149417.54	0.984
86	5096.51	1.001
87	2073.17	1.001
88	1604.54	1.001
89	1533.21	1.001
90	569.51	1.001
91	3710.37	1.001
92	4159.25	1.001
93	1515.22	1.001
94	2277.33	1.001
95	3760.68	1.001
96	1120.48	1.001
97	220142.26	0.995
98	121.36	1.001
99	1267.58	1.001
100	1027.17	1.001
101	1111.23	1.001
102	2307.43	1.001
103	1229.08	1.001
104	2722.61	1.001
105	18.10	0.995
106	29157.31	0.995

TABLE D-5

FRATAR DISTRIBUTION GROWTH FACTOR TWO

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
1	455.30	0.990
2	162.25	0.986
3	2580.55	0.991
4	960.92	0.990
5	6061.00	0.999
6	4128.24	0.999
7	1348.36	0.995
8	2062.67	0.993
9	485.09	0.984
10	3141.23	0.995
11	2457.81	0.998
12	3972.16	0.997
13	25172.34	1.005
14	4182.45	0.998
15	3268.83	0.997
16	5000.95	0.998
17	5422.41	1.000
18	4836.54	1.001
19	3818.98	1.001
20	6406.74	1.003
21	4492.45	0.993
22	2038.29	0.996
23	50.51	0.983
24	470.08	0.987
25	1007.48	1.009
26	809.66	1.009
27	685.72	1.009
28	999.76	1.009
29	1126.78	1.009
30	429.39	0.999
31	579.08	0.993
32	462.76	0.992
33	1832.33	0.998
34	2704.60	1.003
35	5726.91	1.005
36	10854.79	1.002
37	1535.91	1.002
38	1593.75	1.000
39	3483.94	1.001
40	4753.62	1.003

TABLE D-5 (CONT.)

FRATAR DISTRIBUTION GROWTH FACTOR TWO

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
41	3702.32	1.004
42	3545.42	1.003
43	1425.45	0.997
44	1377.65	1.006
45	3118.98	1.001
46	1933.76	1.000
47	411.88	0.988
48	229.02	0.985
49	1040.81	1.009
50	1327.71	0.998
51	2004.82	0.996
52	1727.74	1.001
53	2326.74	0.998
54	774.86	0.997
55	6583.65	1.001
56	1296.96	1.002
57	2724.24	0.996
58	2145.58	0.994
59	3454.99	1.001
60	2203.09	1.001
61	3712.27	1.000
62	3151.18	1.002
63	2003.81	0.998
64	3467.89	1.001
65	1157.37	0.993
66	2418.04	1.000
67	3050.02	1.007
68	2514.26	0.996
69	1771.70	0.998
70	3235.12	1.000
71	1874.26	1.002
72	1568.92	1.002
73	901.23	1.001
74	1668.05	0.996
75	323.32	0.995
76	3637.22	0.998
77	15822.06	1.001
78	1770.83	1.005
79	2299.07	0.981
80	1961.07	1.001

TABLE D-5 (CONT.)

FRATAR DISTRIBUTION GROWTH FACTOR TWO

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
81	1138.61	1.009
82	618.07	0.992
83	2064.75	1.010
84	10389.61	1.012
85	10347.75	0.990
86	5047.61	1.010
87	2054.50	1.010
88	1590.25	1.010
89	1519.56	1.010
90	564.53	1.009
91	3675.77	1.010
92	4120.08	1.010
93	1501.72	1.010
94	2256.73	1.010
95	3725.60	1.010
96	1110.59	1.009
97	29819.67	0.986
98	120.30	1.009
99	1256.36	1.009
100	1018.12	1.009
101	1101.45	1.009
102	2286.55	1.010
103	1218.21	1.009
104	2697.83	1.010
105	18.35	0.981
106	2727.53	0.982

FRATAR DISTRIBUTION GROWTH FACTOR THREE

TABLE D-6

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
1	209.12	0.997
2	160.63	0.996
3	494.66	0.998
4	381.50	0.998
5	3935.82	0.999
6	3805.36	1.000
7	1343.51	0.999
8	1789.90	0.997
9	62.61	0.996
10	951.34	0.998
11	2444.67	1.000
12	7909.56	0.999
13	25203.96	1.004
14	3233.39	1.000
15	2806.03	0.999
16	5391.29	1.000
17	2929.04	1.001
18	4623.12	1.001
19	3328.65	1.000
20	6420.94	1.001
21	6619.57	0.997
22	1170.61	0.999
23	52.22	0.996
24	128.99	0.996
25	1019.89	0.997
26	819.61	0.997
27	694.11	0.997
28	1012.08	0.997
29	1140.68	0.997
30	473.43	0.999
31	425.49	0.999
32	479.41	0.999
33	1547.54	1.001
34	2485.07	1.001
35	6149.86	1.002
36	11085.19	1.002
37	1890.01	1.001
38	1362.12	1.000
39	2898.22	1.001
40	3271.83	1.002

FRATAR DISTRIBUTION GROWTH FACTOR THREE

TABLE D-6 (CONT.)

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
41	3375.89	1.002
42	3571.11	1.001
43	1161.44	1.000
44	1444.73	1.001
45	3140.97	1.001
46	2048.67	1.000
47	284.56	0.997
48	78.71	0.996
49	796.44	1.000
50	1386.65	1.001
51	2025.42	1.001
52	1753.28	1.001
53	2708.91	1.001
54	619.19	0.999
55	4032.33	1.000
56	951.87	1.000
57	960.15	0.999
58	2074.13	1.000
59	3800.43	1.001
60	2863.76	1.000
61	3721.63	1.001
62	3358.62	1.002
63	2038.72	1.000
64	3594.22	1.001
65	1659.89	0.998
66	2581.88	1.001
67	3724.85	1.002
68	2525.51	1.001
69	1996.45	1.000
70	3453.85	1.001
71	1907.28	1.000
72	1629.81	1.000
73	970.54	0.999
74	1745.95	1.000
75	423.42	0.998
76	3910.59	1.001
77	773.50	1.000
78	1994.57	1.002
79	1008.38	0.994
80	817.93	1.000

FRATAR DISTRIBUTION GROWTH FACTOR THREE

TABLE D-6 (CONT.)

ZONE	TOTAL TRIP ENDS	FINAL FACTOR
81	1152.66	0.997
82	233.91	0.997
83	2090.52	0.997
84	10532.88	0.998
85	165.90	0.997
86	5113.14	0.997
87	2080.16	0.997
88	1609.97	0.997
89	1538.40	0.997
90	571.45	0.997
91	3722.67	0.997
92	4172.96	0.997
93	1520.34	0.997
94	2284.98	0.997
95	3773.16	0.997
96	1124.28	0.997
97	362.80	0.997
98	121.77	0.997
99	1271.88	0.997
100	1030.66	0.997
101	1115.01	0.997
102	2315.19	0.997
103	1233.25	0.997
104	2731.74	0.997
105	18.10	0.994
106	35.24	0.995

TABLE D-7

SELECTED TRIP INTERCHANGES FOR GROWTH FACTOR MODELS

FROM	TO	DETROIT 1	DETROIT 2	DETROIT 3	FRATAR 1	FRATAR 2	FRATAR 3
1	41	0.41	0.59	0.34	0.06	.08	0.03
4	47	2.86	1.08	0.37	1.73	.15	0.03
4	91	20.47	16.21	9.06	32.90	23.20	11.11
6	52	0.34	0.78	0.86	0.12	.78	0.82
6	70	8.79	18.57	20.63	3.24	18.46	20.01
6	92	6.43	13.22	15.91	2.17	14.41	24.38
7	33	0.07	0.98	0.90	0.01	.09	0.08
7	73	0.22	0.94	1.27	0.02	.10	0.11
8	38	1.51	2.61	2.19	1.25	2.80	2.07
8	95	4.14	8.06	8.89	4.09	9.03	12.11
9	16	2.50	0.93	0.17	19.95	1.37	0.22
9	36	14.13	2.63	0.47	34.43	3.80	0.63
9	60	5.66	1.00	0.23	1.22	0.15	0.03
10	79	2.22	4.60	0.72	1.10	.82	0.13
11	28	0.49	2.05	2.49	0.29	2.32	3.77
11	29	0.56	2.31	2.81	0.33	2.62	4.25
11	80	4.09	3.95	1.75	3.06	4.08	1.64
11	99	0.62	2.58	3.14	0.37	2.92	4.75
12	22	135.88	48.90	126.67	110.97	112.92	120.57
13	24	14.79	15.27	5.58	38.27	20.24	0.49
13	29	1.37	6.13	3.38	0.47	6.06	14.20
15	87	2.44	5.52	0.04	0.90	5.90	9.15
16	53	9.65	19.61	[illegible]	3.24	19.84	20.93
16	68	7.09	16.70	18.93	2.43	10.95	17.41
16	88	0.77	3.56	5.14	0.24	3.90	1.22
17	30	0.64	1.60	1.07	0.32	1.02	0.47
17	32	5.39	2.25	0.03	11.50	11.47	[illegible]
17	90	1.02	2.50	1.70	0.43	[illegible]	[illegible]

TABLE E-7 (cont.)

FROM	TO	DETROIT 1	DETROIT 2	DETROIT 3	FRATAR 1	FRATAR 2	FRATAR 3
17	91	6.70	17.23	12.11	2.33	17.65	19.40
19	54	2.21	6.25	5.10	0.76	6.46	4.79
20	37	2.31	14.77	23.49	0.78	14.52	22.40
20	56	1.15	11.97	11.58	0.41	11.63	11.00
21	38	5.72	3.55	4.99	2.50	3.76	4.75
21	101	6.15	4.22	7.70	3.31	4.77	10.33
23	24	0.08	0.13	0.05	0.07	0.02	0.00
23	62	0.02	0.11	0.16	0.01	0.02	0.02
24	43	2.17	1.29	0.30	0.67	0.18	0.03
25	36	0.30	2.13	3.01	0.07	2.25	5.24
25	44	0.44	2.21	3.58	0.07	2.14	5.43
26	87	2.04	14.15	22.35	0.53	9.21	17.10
27	48	0.54	1.13	0.59	1.02	1.94	0.70
27	68	0.59	2.06	2.55	0.17	2.49	4.17
27	82	0.61	1.33	1.28	0.07	2.01	1.50
28	38	0.42	2.01	3.16	0.09	2.78	4.82
28	71	0.92	2.74	3.65	0.22	2.76	5.70
28	90	0.69	4.75	7.45	0.18	3.10	6.04
29	91	5.08	35.33	57.20	1.32	23.19	46.21
30	35	2.73	17.69	26.73	0.75	17.36	25.10
30	74	1.18	5.32	6.96	0.37	5.39	5.97
30	83	0.45	3.08	4.70	0.08	3.22	6.33
30	94	0.49	3.37	5.15	0.09	3.52	6.93
34	62	7.32	40.41	49.65	1.90	39.11	47.66
35	82	2.38	6.79	4.72	0.72	8.19	4.75
35	83	0.62	4.05	6.38	0.12	4.16	11.01
36	45	34.24	170.55	215.32	9.62	167.42	213.41
36	54	5.01	29.45	28.91	1.35	29.95	27.96
37	87	0.31	3.46	0.23	0.06	3.72	10.04
38	43	0.49	1.13	0.91	0.03	0.12	0.08
40	67	5.91	38.54	41.49	1.36	36.43	42.93

TABLE D-7 (cont.)

FROM	TO	DETROIT 1	DETROIT 2	DETROIT 3	FRATAR 1	FRATAR 2	FRATAR 3
41	67	5.16	25.21	41.11	1.15	23.69	39.04
41	78	4.66	26.14	52.66	1.09	34.27	50.17
41	74	3.23	15.13	18.08	0.83	14.96	10.92
42	56	1.35	23.39	23.98	0.50	22.94	22.73
42	79	1.66	5.08	3.14	0.39	0.87	0.57
43	46	8.63	22.67	22.88	4.90	22.89	20.34
45	60	3.88	18.40	30.57	0.99	18.18	20.78
45	62	1.37	5.92	7.74	0.38	5.80	7.44
46	83	0.70	4.95	7.59	0.13	5.19	11.94
48	100	23.50	4.35	0.03	20.37	0.86	0.00
49	94	1.14	5.59	7.31	0.14	4.88	10.10
50	70	3.34	20.64	20.91	1.13	20.80	25.26
50	94	0.86	5.11	7.14	0.27	5.97	10.94
51	62	11.19	48.77	60.46	3.71	49.13	57.50
52	53	20.77	71.39	102.55	5.57	71.10	95.21
52	85	13.93	14.91	0.37	4.21	13.75	0.35
54	75	0.01	0.44	0.90	0.00	0.56	0.73
54	77	630.25	70.18	3.01	691.98	77.59	2.56
58	84	13.16	22.07	41.70	7.72	39.25	62.52
59	66	15.13	73.54	105.20	4.10	72.10	100.76
59	106	8.03	5.70	0.11	2.10	0.31	0.02
61	69	2.11	28.09	47.49	0.02	27.82	44.92
65	69	1.83	22.32	66.61	0.32	24.59	60.08
65	80	2.10	2.21	1.85	0.93	2.52	1.58
68	82	0.02	0.90	0.53	0.03	0.12	0.05
68	103	1.04	3.68	4.56	0.30	4.44	7.44
69	105	0.00	0.03	0.07	0.00	0.01	0.01
71	88	1.47	4.38	5.80	0.34	4.41	3.12
73	96	0.32	2.30	3.69	0.04	1.39	5.40
75	95	0.03	2.93	9.42	0.00	[illegible]	11.33
79	100	4.29	19.55	17.34	1.50	34.50	14.70

TABLE D-7 (cont.)

FROM	TO	DETROIT 1	DETROIT 2	DETROIT 3	FRATAR 1	FRATAR 2	FRATAR 3
79	102	9.66	42.11	28.30	19.10	77.18	33.68
80	100	3.44	5.52	3.10	0.90	5.89	4.41
81	85	71.68	67.83	1.81	9.66	80.79	2.03
84	91	47.50	361.47	610.57	12.26	225.35	482.21
85	92	260.47	251.95	6.82	35.01	297.46	7.67
87	93	3.78	26.40	41.94	0.99	17.15	33.96
88	93	2.92	20.35	32.18	0.70	13.25	26.66
93	69	0.15	2.84	5.82	0.08	2.66	9.02
93	96	0.32	14.15	22.33	0.52	9.23	18.09
94	97	805.64	445.76	6.81	1252.92	590.64	7.81

TABLE [illegible]

SELECTED GRAVITY MODEL TRIP INTERCHANGES

FROM	TO	WORK TRIPS	COMMERCIAL TRIPS	HOME BASED OTHER TRIPS	NON HOME BASED OTHER TRIPS
1	41	0.00	0.00	0.82	0.00
4	47	1.71	1.69	0.63	3.93
4	91	0.00	0.00	1.27	0.00
6	52	0.00	0.00	1.52	0.00
6	70	0.00	0.00	4.98	0.00
6	92	0.00	0.00	1.43	0.00
7	33	6.10	0.00	0.00	0.00
7	73	5.31	0.00	0.00	0.00
8	38	0.11	2.20	0.46	0.00
8	95	0.00	0.00	0.97	0.00
9	16	0.00	0.00	7.21	0.00
9	36	3.86	26.97	3.72	0.00
9	60	0.00	0.00	1.79	0.00
10	79	0.02	0.54	0.01	0.00
11	28	0.00	0.00	1.09	0.00
11	29	0.00	0.00	1.21	0.00
11	80	0.68	0.55	0.34	0.00
11	99	0.00	0.00	1.73	0.00
12	22	36.23	215.10	31.44	0.00
13	24	0.00	0.00	0.00	0.00
13	29	162.13	0.00	0.00	0.00
15	87	0.00	0.00	0.55	0.00
16	53	0.00	0.00	10.52	0.00
16	68	0.00	0.00	5.90	0.00
16	88	1.43	0.72	.39	1.09
17	30	0.00	0.00	0.00	0.00
17	32	0.00	0.00	0.00	0.00

TABLE D-8 (cont.)

FROM	TO	WORK TRIPS	COMMERCIAL TRIPS	HOME BASED OTHER TRIPS	NON HOME BASED OTHER TRIPS
17	90	0.57	2.57	0.36	0.00
17	91	3.58	13.55	2.52	0.00
19	54	5.11	58.82	5.74	0.00
20	37	0.00	0.00	0.00	0.00
20	56	0.00	0.00	0.00	0.00
21	38	1.78	9.11	2.15	0.00
21	101	9.45	7.55	6.31	25.33
23	24	0.00	0.00	0.00	0.00
23	62	1.43	0.25	0.11	1.51
24	43	0.00	0.00	0.00	0.00
25	36	0.00	0.00	0.00	0.00
25	44	0.00	0.00	0.00	0.00
26	87	0.15	1.03	0.10	0.00
27	48	6.04	2.81	3.73	7.14
27	68	0.00	0.00	1.54	0.00
27	82	0.00	0.00	0.35	0.00
28	38	0.42	4.22	0.80	0.00
28	71	0.00	0.00	0.67	0.00
28	90	0.00	0.00	0.24	0.00
29	91	0.00	0.00	2.20	0.00
30	35	0.00	0.00	0.00	0.00
30	74	7.28	1.41	1.09	0.00
30	83	7.65	1.14	1.95	0.00
30	94	2.42	0.46	0.63	0.00
34	62	0.00	0.00	5.98	0.00
35	82	3.33	2.91	2.45	0.00
35	83	8.02	26.95	6.12	0.00
36	45	27.88	140.35	11.68	0.00
36	54	0.00	0.00	0.00	0.00
37	87	1.43	5.32	0.97	0.00

TABLE D-8 (cont.)

FROM	TC	WORK TRIPS	COMMERCIAL TRIPS	HOME BASED OTHER TRIPS	NON HOME BASED OTHER TRIPS
38	43	0.00	0.00	0.00	0.00
40	67	29.23	3.17	2.58	79.01
41	67	28.95	2.71	2.56	51.97
41	78	10.34	1.01	0.77	8.24
41	74	0.00	0.00	4.00	0.00
42	56	8.98	0.00	1.16	11.04
42	79	0.54	4.14	0.28	0.00
43	46	9.95	1.16	1.29	10.99
45	60	0.00	0.00	10.56	0.00
45	62	0.00	0.00	0.48	0.00
46	83	0.00	0.00	1.24	0.00
48	106	5.56	6.58	0.00	9.12
49	94	6.18	1.35	1.69	7.32
50	70	4.16	0.29	0.55	4.43
50	94	6.21	1.36	1.70	5.50
51	62	0.00	0.00	6.88	0.00
52	53	0.00	0.00	77.43	0.00
52	85	0.00	0.00	0.83	0.00
54	75	0.86	1.41	0.58	0.00
54	77	0.00	0.00	0.00	0.00
58	84	0.00	0.00	6.92	0.00
59	66	0.00	0.00	34.65	0.00
59	106	0.00	0.00	0.56	0.00
61	69	0.00	0.00	17.23	0.00
65	69	45.90	2.53	9.32	62.24
65	80	0.00	0.00	0.00	0.00
68	82	0.00	0.00	5.70	0.00
68	103	0.00	0.00	0.31	0.00
69	105	0.00	0.00	0.00	0.00
71	88	6.41	1.33	[illegible].72	[illegible].03

TABLE D-3(cont.)

FROM	TO	WORK TRIPS	COMMERCIAL TRIPS	HOME BASED OTHER TRIPS	NON HOME BASED OTHER TRIPS
73	96	0.00	0.00	0.63	0.00
75	95	0.00	0.00	1.10	0.00
79	100	0.09	1.42	0.19	0.00
79	102	0.00	0.00	0.00	0.00
80	100	0.48	0.29	0.33	0.00
81	85	0.00	0.00	3.55	0.00
84	91	0.00	0.00	104.17	0.00
85	92	0.00	0.00	5.98	0.00
87	93	0.00	0.00	0.05	0.00
88	93	10.64	2.11	0.05	11.50
93	69	0.00	0.00	4.88	0.00
93	96	0.00	0.00	3.90	0.00
94	97	6.76	32.43	5.82	0.00

TABLE D-9

SELECTED GRAVITY MODEL K FACTORS

FROM	TO	WORK TRIPS	COMMERCIAL TRIPS	HOME BASED OTHER TRIPS	NON HOME BASED OTHER TRIPS
1	41	1.00	0.00	1.00	1.00
4	47	1.00	0.00	1.00	0.00
4	91	1.00	0.00	1.00	1.00
6	52	1.00	0.00	1.00	1.00
6	70	1.00	0.00	3.10	1.00
6	92	1.00	0.00	1.00	1.00
7	33	0.00	0.00	0.00	1.00
7	73	1.00	0.00	1.86	1.00
8	38	0.43	0.41	0.93	0.00
8	95	1.00	0.00	1.00	1.00
9	16	1.00	0.00	1.00	1.00
9	36	1.00	0.53	1.78	0.00
9	60	1.00	0.00	1.00	1.00
10	79	1.00	0.00	3.60	1.00
11	28	1.00	0.00	1.00	1.00
11	29	1.00	0.00	1.00	1.00
11	80	1.19	0.00	2.11	0.00
11	99	1.00	0.00	1.00	1.00
12	22	5.47	2.32	3.94	0.00
13	24	1.00	1.00	1.00	0.00
13	29	1.00	1.00	1.00	1.00
15	87	1.00	0.00	1.00	1.00
16	53	1.00	0.00	3.17	1.00
16	68	1.00	0.00	2.89	1.00
16	88	1.00	0.00	1.00	1.00
17	30	1.00	1.00	1.00	.00
17	32	1.00	1.00	1.00	0.00
17	90	1.00	1.00	1.00	0.00
17	91	1.00	1.00	1.00	0.00

TABLE I-9 (cont.)

FROM	TO	WORK TRIPS	COMMERCIAL TRIPS	HOME BASED OTHER TRIPS	NON HOME BASED OTHER TRIPS
19	54	2.43	1.95	2.97	2.08
20	37	1.00	1.00	1.00	0.00
20	56	1.00	1.00	1.00	1.00
21	38	1.00	0.28	0.59	0.00
21	101	0.00	0.00	6.31	1.00
23	24	1.00	1.00	1.00	0.00
23	62	0.00	0.00	0.00	1.00
24	43	1.00	1.00	1.00	0.00
25	36	1.00	1.00	1.00	1.00
25	44	1.00	1.00	1.00	0.00
26	87	1.00	1.00	1.00	1.00
27	48	1.00	1.00	1.00	1.00
27	68	1.00	1.00	1.00	1.00
27	82	1.00	1.00	1.00	1.00
28	38	1.00	1.00	1.00	0.00
28	71	1.00	1.00	1.00	1.00
28	90	1.00	1.00	1.00	1.00
29	91	1.00	1.00	1.00	1.00
30	35	1.00	1.00	1.00	0.57
30	74	1.16	0.91	1.15	1.39
30	83	1.00	1.00	1.00	0.00
30	94	1.00	1.00	1.00	0.00
34	62	1.00	0.00	3.01	1.00
35	82	0.96	1.44	1.39	2.19
35	83	1.00	1.00	1.00	0.00
36	45	1.38	1.07	1.52	0.95
36	54	1.00	1.00	1.00	0.00
37	87	1.00	1.00	1.00	0.00
38	43	1.00	1.00	1.00	0.00
40	67	1.24	1.22	1.14	0.87
41	67	1.19	0.59	0.45	0.54
41	78	2.23	1.12	1.37	1.27

TABLE L-9 (cont.)

FROM	TO	WORK TRIPS	COMMERCIAL TRIPS	HOME BASED OTHER TRIPS	NON HOME BASED OTHER TRIPS
41	74	1.00	0.00	3.10	1.00
42	56	1.78	1.09	1.38	1.47
42	79	1.00	0.00	1.00	1.00
43	46	0.98	0.62	0.97	1.28
45	60	1.00	0.00	1.22	1.00
45	62	1.00	0.00	0.26	1.00
46	83	1.00	0.00	1.00	1.00
48	106	0.00	0.00	0.00	1.00
49	94	1.00	1.00	1.00	0.00
50	70	1.05	0.62	1.14	1.15
50	94	1.00	1.00	1.00	0.00
51	62	0.25	0.00	4.60	1.00
52	53	1.00	0.00	7.80	1.00
52	85	1.00	0.00	1.00	1.00
54	75	0.00	2.32	0.00	0.00
54	77	0.00	0.00	0.00	0.00
58	84	1.00	0.00	1.00	1.00
59	66	1.00	0.00	5.44	1.00
59	106	0.00	0.00	0.56	0.00
61	69	1.00	0.00	2.43	1.00
65	69	3.21	1.62	3.35	3.19
65	80	1.00	1.00	1.00	0.00
68	82	1.00	0.00	1.00	1.00
68	103	0.00	0.00	1.07	1.00
69	105	0.00	0.00	0.00	1.00
71	88	1.00	0.00	1.00	1.00
73	96	1.00	0.00	1.00	1.00
75	95	1.00	0.00	1.00	1.00
79	100	1.00	1.00	1.00	1.00
79	102	1.00	1.00	0.00	1.00
80	100	1.00	1.00	1.00	0.00
81	85	1.00	1.00	1.00	1.00

TABLE D-9 (cont.)

FROM	TO	WORK TRIPS	COMMERCIAL TRIPS	HOME BASED OTHER TRIPS	NON HOME BASED OTHER TRIPS
84	91	1.00	1.00	1.00	1.00
85	92	1.00	0.00	1.00	1.00
87	93	1.00	1.00	1.00	1.00
88	93	1.00	1.00	1.00	1.00
93	69	1.00	1.00	1.00	1.00
93	96	1.00	1.00	1.00	1.00
94	97	1.00	1.00	1.00	0.00

APPENDIX L

STREET CODE ILLUSTRATION

N 27th St.	Laf	/001-63-99/351-57-650/1000-55-2099/
S 27th St.	Laf	/001-63-310/311-66-705/706-68-999/
N 28th St.	Laf	/001-63-99/200-57-699/
S 28th St.	Laf	/001-63-310/311-66-709-68-1399/
N 29th St.	Laf	/001-63-99/200-57-899/1500-55-1699/
S 29th St.	Laf	/001-63-310/311-66-709/710-68-1099/
N 30th St.	Laf	/001-63-149/150-57-899/
S 30th St.	Laf	/001-63-310/311-66-709/710-68-1211/
N 31st St.	Laf	/001-63-160/500-57-799/
S 31st St.	Laf	/001-63-310/311-66-709/710-68-1099/
Adams St.	Laf	/900-72-910/911-70-1616/1617-69-1999/
Agricultural Mail	WL	/All in 20/
Airport Rd.	WL	/0-EVEN 21-500/
Alabama St.	Laf	/001-32-199/200-EVEN-37-ODD 32-214//215-33-410/411-34-699//1000-EVEN 61-ODD 34-1099/1100-61-/1699
Albany St.	Laf	/2000-EVEN 51-ODD 52-2014/2015-53-/2599/
Alder Dr.	Laf	/1000-84-1205/
Algonquin	Laf	/2900-86-2950/
Allen St.	WL	/600-14-816/816-6-999/
America St.	Laf	/100-30-299/

APPENDIX E (cont.)

STREET CODE ILLUSTRATION

Andrew Pl.	WL	/101-18-114/115-16-199/
Apache Dr.	Laf	/2300-86-2431/
Arapahoe Dr.	Laf	/2000-86-2217/
Archway	Laf	/1000-84-1240/